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Soil Map Units and Crop Production in Western Beaver County, Alberta

by

(C) Nancy Marie Finlayson

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Soil Map Units and Crop Production in Western Beaver County, Alberta submitted by Nancy Marie Finlayson in partial fulfilment of the requirements for the degree of Master of Science.

Abstract

Relationships between crop productivity and soil map units derived from a semi-detailed soil survey were examined in western Beaver County, Alberta. Crop yield data for wheat, barley, oats and rapeseed collected by the Alberta Hail and Crop Insurance Corporation, and farm input information from a series of interviews with area farmers were analyzed statistically.

Poor correlations were found between crop yields and most soil map units. This was probably a result of a lack of compatibility between the level of detail of soil mapping, and the resolution of crop yield estimates. When soil map units were grouped according to dominant Soil Series, relationships improved for most crops, allowing the formulation of a rough index of productivity.

Most farm input and demographic factors correlated poorly with soil map units. Soils had little influence on soil management and input decisions. Some evidence existed that dominantly Black Solodized Solonetzic soil map units are more likely to be subject to crop failure than dominantly Black Chernozemic soil map units.

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I. The Problem

One of the basic objectives of the production of a soil survey map is to provide practical insight into the efficient use of the soils described (Mackney 1969; Lee and Ryan 1966; Bartelli 1978). Much of the soil survey effort in the agricultural areas of Canada takes the form of semi-detailed surveys, at scales of mapping ranging from 1:25 000 to 1:100 000. These form an important part of the information required for the evaluation of land for agriculture in most parts of Canada.

Soil survey maps and reports provide detailed pedon descriptions, descriptions of individual soil "series" and associations of soil "series" as well as information on the climate, vegetation, parent geological material and topography found in an area. In addition, soil map units are usually classified according to soil capability for agriculture, using the Canada Land Inventory (CLI) System. Unfortunately there appears to be little quantitative basis for these capability ratings in most cases.

Several attempts have been made in southern Ontario to quantify Canada Land Inventory capability classes for agriculture, in terms of crop yields for various crops (Hoffman 1978; van Vliet et al 1979; Noble 1965). However, no similar work has been carried out in western Canada, except at a very broad level of generalization (Peters 1977). Because of differences in climate, range of crops cultivated, and crops used as a basis for the

classification, the relationship between crop yield and CLI Capability Class for Agriculture probably differs between eastern and western Canada. These differences have not been closely examined.

Farmers' inputs into crop production are important to any evaluation of land capability for agriculture. Two areas producing equal crop yields cannot be considered of equal productivity if one requires twice as much fuel or other inputs as the other. This aspect of land capability has largely been ignored in the past.

If CLI ratings are to be consistently and usefully applied to soil map units derived from semi-detailed soil surveys in Alberta, more information concerning the relationships between soil map units, crop yields and farmers' inputs under conditions of climate, soils, and methods of farm management found in western Canada must be obtained.

A. Objectives, Assumptions and Delimitations of the Study

This study attempts to evaluate the usefulness of information derived from a recent semi-detailed soil survey of western Beaver County, Alberta in determining the agricultural productivity of the area. The following hypotheses are examined:

1. Crop yields of common field crops vary significantly between soil map units in the study area; and
2. Farmers' inputs into crop production differ

significantly between soil map units in the study area.

In addition, the study attempts to carry out the following:

1. Assign relative productivity ratings to map units on the basis of crop yield and input information if possible; and
2. Assess the usefulness of information derived from a semi-detailed soil survey in evaluating the productivity of land in western Beaver County.

Two assumptions basic to this study were made:

1. Wheat, barley, rapeseed and oat yields are adequate indicators of soil productivity in western Beaver County; and
2. The soil survey of Beaver County is a standard semi-detailed soil survey as currently carried out in Alberta.

This study does not attempt to predict optimum or average yields for any specific map unit, nor is it intended to assess the quality of the soil survey information used.

II. Literature Review

A. Land Evaluation

Land can be defined as:

> "a specific area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic attributes of the biosphere, vertically above and below this area, including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity--to the extent that these attributes exert a significant influence on present and future uses of the land by man" (FAO 1976).

Any attempt to evaluate land for a given purpose must therefore encompass not only the physical characteristics normally associated with land-the soil, topography, hydrology and biology of an area-- but also the cultural and social patterns man has imposed upon the land.

The evaluation of land generally implies a ranking or ordering of land qualities relevent to specific land uses. In order to define an area as being "good" for a particular use, both the physical capability of the land for that use, and the utility of the land to economically produce goods currently in demand must be considered (Gibbons and Haans 1974). Although the physical characteristics of land generally form the basis for its evaluation, these can be altered or even overridden by associated social and economic factors.

Guidelines to land evaluation proposed by the Food and Agriculture Organization of the United Nations (FAO 1976)

suggest two different approaches to land evaluation:

1. A two-stage approach in which qualitative physical land evaluation is followed by an economic and social analysis; and
2. A parallel approach in which the physical land evaluation procedure is carried out concurrently with an economic and social analysis.

The two-stage approach is most useful in resource inventories required for broad regional or national planning purposes. The qualitative nature of the physical land evaluation however, drastically limits the detail and usefulness of any economic and social analysis which may follow.

The parallel approach is more efficient, as data collection can be designed specifically for collection of both types of information. The parallel approach necessitates co-operation between the natural and social scientists, a situation which can only improve the quality and efficiency of the evaluation process, and the worth of resulting planning decisions.

The FAO guidelines for land evaluation were developed in the early 1970's, as an attempt to standardize the many systems of land evaluation currently being used around the world. The German system for example, has been in use since 1934 (Weiers 1975). Every hectare of non-urban land in the country has been classified according to soil, climate, size of farm, farming conditions, and yield potential relative to

the soils considered to be the best in the country. Information about economic conditions, such as regional prices and wages, and regional advantages and disadvantages are added to this inventory to produce an index for each field which Weiers and Reid term "farming value". This system has been used for tax assessment, determing land prices and rents, and urban and regional planning (Weiers and Reid 1974).

In Czechoslovakia, computer stored economic information such as crop yields, and information about inputs and markets are applied to data on the climate, soil, and site of land. Information about crop yields, labour and material costs, fertilizers, cultivation and conservation practices, services and equipment are derived from an extensive system of small plots (FAO 1975).

In the Netherlands, a multi-disciplinary team has quantitatively evaluated land for agriculture (Vink 1960). A standard soil survey is used as its base. Economic information is added, derived from several sources:

1. Active farms in different areas of the country, which provide information about yield, its monetary value, fertilizer costs, and other production costs per hectare;
2. Yield information from experimental plots; and
3. Crop surveys and pasture vegetation surveys.

A suitability rating measured in monetary units is derived from this information, using the following

mathematical relationship:

$$Sa=((R\times Y)\times E-(F+C)E')ETM$$

where:

Sa is the suitability rating of soil A in monetary units;

R is the acreage of a crop as a percentage of total farm area;

Y is yield of crop on soil A;

F is fertilizers used on soil A;

C is all other farming costs;

E and E′ are economic parameters for a given situation;

ETM indicates the economic, technical, and management situations considered.

Preliminary results indicate a range of soil suitability ratings in the country, from 24 monetary units for an excessively drained sand humic podzol, to 1122 monetary units for a well drained loam alluvial soil.

B. Land Capability Classification

Despite the emphasis by FAO and some European systems of land evaluation on a multidisciplinary approach, evaluation of the physical aspects of land alone is by far the most commonly used approach to land evaluation. It is most often used in the formulation of broad inventories for general planning at a national or regional level. The physical properties of land are generally rated qualitatively according to their suitability or capability

for particular uses. Land capability classification is generally considered to be a grouping of soil mapping units derived from soil survey maps and reports, based on the inherent capacity of the land to perform at a given level, for a general use (FAO 1976). It is the basis of the qualitative evaluation of the physical aspects of land-the soil site and climate--suggested as the first stage of the FAO two-stage approach to land evaluation, for a study of a very general nature.

USDA Land Capability Classification

The United States Department of Agriculture, Soil Conservation Service's Land Capability Classification was the first such classification to be developed, and has served as a model for several other national systems, most notably the Agricultural Land Classification of the United Kingdom Ministry of Agriculture, and the Canada Land Inventory Soil Capability Classification for Agriculture.

Based on detailed soil survey information collected at mapping scales less than 1:20 000 (Olsen 1974), it attempts to delineate areas of land with similar capability and limitations for sustained agricultural production, but not areas requiring similar management practices. Subclasses are separated according to the nature of the limitation to agriculture, such as erosion problems or climatic limitations. Land is categorized into 8 classes, depending on the degree of limitation, based on the following assumptions:

1. It is an interpretive classification of soil survey information, based on climate and permanent soil characteristics and qualities. Soils within a class are similar only in the degree of agricultural limitation;
2. The ratio of output to input based on long term economic trends is a criterion, but the classification is not a productivity rating for specific crops;
3. Moderately high levels of management are assumed;
4. Soils are not grouped according to their most profitable use;
5. Where soils can be economically improved on a permanent basis, they are classified as if the improvements had been completed. An area may be reclassified where a major reclamation project permanently alters the limitations to agriculture;
6. Socio-economic factors such as distance to markets are not considered;
7. Wherever possible, experimental data, recorded observations and experience are the bases for classification. Where such information is lacking, soils are grouped according to an interpretation of their basic characteristics.

Subclasses are separated on the basis of the type of limitation to agriculture an area exhibits. These include effective soil depth, texture of the surface horizon, permeability, drainage, available water holding capacity, slope, erosion hazard, flooding hazard, salinity, alkalinity

and toxicity, frost free period, and climatic indices (Olsen 1974).

<u>Canada Land Inventory Soil Capability Classification for Agriculture</u>

The Canada Land Inventory Soil Capability Classification for Agriculture is based on the USDA system outlined above, but is altered to suit the Canadian situation. It is part of a broad survey of land capability and use, designed as a general resource inventory for planning purposes. In addition to the soil capability classification for agriculture, classifications of land capability for forestry, land suitability for recreation, and land capability for wildlife have been devised.

Soil Capability for Agriculture maps have been published at a scale of 1:250 000, based on mapping carried out at larger scales. Soils are grouped into seven classes according to their relative limitations to the production of certain agricultural crops. Classes 1 to 4 are considered to have varying degrees of capability for crops, classes 5 and 6 are capable of producing only perennial forage crops, and class 7 has no capability for cultivated agriculture or permanent pasture.

Like the American system, subclasses are separated on the basis of limitations to agriculture due to the physical characteristics of climate, soil, and site. Climate, adverse soil structure or permeability, erosion, low fertility, inundation or excess water, moisture limitation, salinity,

stoniness, depth of consolidated bedrock, topography, or combinations of the above factors are all considered. Unlike the USDA system, climate is considered the overriding limitation. No soil can be placed in a class higher than that dictated by its climatic limitation. Additional soil or site limitations serve to further reduce the class of the land.

The assumptions of the CLI soil capability classification for agriculture differ on two important points from those of the USDA Land Capability classification:

1. Input-output ratios are not criteria for classification. It is more a classification of soil than a classification of land as previously defined (FAO 1976).
2. Mapping of the U.S. classification takes place using soil survey information collected at scales of 1:20,000 or less, scales which Young (1973a) considers suitable for localized feasibility, or development surveys. Maps using the Canadian system have been published primarily at a scale of mapping of 1:250 000, based on soil survey information mapped at 1:50 000 to 1:200 000. These are scales considered by Young to be useful only for broad regional resource inventories. This is an important point, as it is indicative of basic differences in the terms of reference of the two systems.

Although considered by some to be one of the most comprehensive systems of land classification in the world

today, (Hansen 1977, Young 1973b) the Canada Land Inventory suffers from several drawbacks which restrict its usefulness to some extent:

1. Like the USDA's Land Capability Classification, it considers a narrower concept of land than that defined by FAO (1976) because of its exclusion of socio-economic factors;
2. Although well suited to the broad resource inventories for which it was developed, the system requires modification through the consideration of more quantitative data when applied to projects requiring more detail;
3. The system is difficult to quantify, which hampers a detailed economic analysis.
4. As different crops have been considered the basis for evaluation in different parts of Canada, classes are not equivalent between regions. Class 1 land in southern Ontario is not equivalent to class 1 land in Alberta, where climatic and soil conditions are quite different. Hansen (1977) argues that areas capable of producing the widest variety of crops should have a higher rating than those where crop variety is restricted. This has not been the case in the application of the Canada Land Inventory Soil Capability Classification for Agriculture across Canada as a whole.

C. Quantification of Soil Capability

Many workers have stressed the importance of basing soil capability interpretations, at any but the broadest level of generalization, on quantitative soil productivity information (Vink 1960, FAO 1976, Young 1973b, Trudgill and Briggs 1977, Avery 1962, Weeks and Snyder 1957). This involves the acquisition of detailed, soil specific, quantitative data on crop yields, so that a mathematically derived yield prediction model can be formulated. Equally detailed farm input information about specific soils is also required, before soil capability can be fully quantified.

Quantifying Crop Yield Information With Respect to Soils

The prediction of yields to be expected under specific levels of management is the most important aspect of quantifying soil capability. Studies attempting to quantify crop yields to allow a reliable prediction of yield have generally used one of two different approaches:

1. The relating of soil survey map units, usually generic taxonomic groupings of soils, to crop yields; and
2. The search for a relationship between crop yields and the qualitative capability classification of the soils of the area.

Soil Map Units and Crop Yields

Quantification of soil capability by attempting to relate soil survey mapping units mapped at various levels of intensity, to the crop yields produced on them, is the simplest and most direct approach. If soil

survey mapping units can be shown to correlate closely with crop yields, productivity classification for a soil map is a relatively simple matter, since most of the information about the physical base is derived from soil survey maps and reports. This has been the approach taken by the USDA Soil Conservation Service. "Bench-mark" soils are correlated to the yields obtained on them, which are determined from long term plot studies and farmers' records (Avery 1962). Odell's study of farmers' crop yield records in Illinois is a good example of this type of work (Odell 1958).

Butler(1964), however questions the idea that crop response is in fact closely related to soil mapping units, and argues that the properties affecting crop productivity are not always those defining the soil map unit or generic taxonomic unit. Soil properties significantly limiting crop growth are often confounded in soil map units with non-significant properties, making interactions difficult or impossible to analyze. He concludes that after an examination of some early, largely qualitative attempts to correlate soil survey units with yield, that:

> "The correlation...between soil types and agricultural production is uncertain or absent" (Butler 1964).

More recent studies have attempted to establish a relationship between soil map units and crop production. Lee and Ryan (1966) in Ireland studied the relationship

between sugar beet yield and four diverse soil mapping units, described at the soil series level. Sugar beet yield data were obtained over a 2 year period from farms chosen on the basis of their high level of management. Considerable additional sugar beet yield data for a four year period were obtained from the Irish Sugar Company. Although this information covered a longer time period, it had the disadvantage that the level of farm management was unknown.

Analysis of variance techniques revealed statistically significant differences in sugar beet yields between soil mapping units on both sets of data. Lee and Ryan concluded however, that a further breakdown of the soil mapping units into units described at the soil phase level would have been even more useful in predicting crop yield.

Cruikshank and Armstrong (1971) working in Northern Ireland, examined the relationships between gross margin (gross returns less operating costs) based in part on crop yield information, soil map units mapped at 1:10 560, and soil properties considered limiting to crop growth. Seventy farms were examined on ten different soil series units. Barley, oats, potatoes, livestock, and a composite farm unit were considered.

Cruikshank and Armstrong found a good relationship between gross margin and soil properties, although it varied a great deal from crop to crop. Soils definitely

influenced gross margin, but the soil series map unit did not describe the spatial variability of the limiting properties adequately in all cases. Moisture holding capacity and per cent weight of soil particles less than .005 mm. did not vary significantly between soil series as mapped. Cruikshank and Armstrong concluded that more information was required concerning the spatial variation of values of limiting soil properties within and between map units, before soil series mapping units could be used directly for land capability classification.

Webster and Beckett (1973) re-examined the Cruikshank and Armstrong data using analysis of variance techniques to analyze the relationships between soil series map units and gross margin, rather than the regression method incorporating soil properties which Cruikshank and Armstrong used. They concluded that the soil map units had greater value for predicting potato yield than consideration of soil properties alone, and only slightly less value for barley and livestock yield prediction. In addition, they pointed out the considerable savings in time and cost involved in the determination of soil series units in the field, compared to the cost of extensive laboratory analysis of soil properties.

Weeks and Snyder(1957) attempted to discover directly the soil properties affecting yields of Yellow

Newtown apples in California. Using multiple regression techniques, they developed a set of variables quantitatively describing soil properties, which along with tree-age variables, was able to explain 44% of apple yield variation. With the addition of slope and management practice variables, the percentage apple yield explained by the equation rose to 87%. This probably illustrates the degree to which apple farmers have been able to overcome soil limitations by using appropriate management techniques.

Very little of this type of work has been carried out in Canada, and certainly nothing has been done using soil survey information as detailed as that of the above studies. Sheppard and Williams(1976) attempted to relate cereal yields obtained for crop yield districts in the three prairie provinces to Great Soil Groups, derived from the Soil Map of Canada.

Correlations on the whole were poor, but an ordering of Great Soil Groups according to yield was possible. Chernozemic soils tended to have the highest yields, but Dark Brown Chernozems outproduced Black Chernozems, a rather surprising result. Because of the level of intensity of this study and the non-specific nature of the crop yield information (arable portions of the three prairie provinces were subdivided into only 42 crop districts) the soil-crop yield relationships derived here are not precise enough to be of much use in

rating the capability of soils.

Peters(1977) analyzed a large body of crop yield data for wheat, oats, and barley, from central Alberta and the Peace River area of Alberta, obtained from the Alberta Hail and Crop Insurance Corporation. Soils information derived from soil survey maps was input at the soil series level, but the smallest areal unit considered was one section of land (one square mile). This allowed considerable soil variation within series designations. Despite this, yield differences were found between soils of different soil series, but climate appeared to be the most influential factor in dictating crop yield.

These studies indicate that the relationships between soil survey map units, soil properties and crop production, are far from being well established particularly in western Canada. It appears that they vary considerably depending upon the crop, the area in which the study was undertaken, and the nature of the soil. The level of intensity of the original soil survey is most important, and it appears likely that mapping at least at the soil phase level of detail, is necessary for highly reliable yield prediction.

Work carried out in Canada to date has not been on a sufficiently detailed scale to indicate the nature of soil map unit-crop yield relationships, but it does indicate some possibility of success for more detailed

studies in the future.

Qualitative Capability Classes and Crop Yields

Several attempts have been made in Canada to quantify Canada Land Inventory Soil Capability classes for agriculture, by statistically relating them directly to crop yields, or indicators of crop yield. Noble(1965) related gross farm income from dairy-general farms in eastern Ontario, to the CLI Capability classifications of the farms. He found that farms with more than 135 acres of class 2 soil, or 160 acres of class 3 soil were likely to have an above average income, while smaller farms were generally less successful. Based on such findings as these, Noble devised an "adjusted acre" unit, where:

1 acre of class 1 soil = 1.00 adjusted acres

1 acre of class 2 soil = 0.87 adjusted acres

1 acre of class 3 soil = 0.75 adjusted acres

1 acre of class 4 soil = 0.33 adjusted acres

1 acre of class 5 soil = 0.25 adjusted acres

1 acre of class 6 soil = 0.20 adjusted acres

When applied to another 300 farms in the same area, the classification was able to reliably group farms according to gross income especially in the upper 3 CLI classes.

Hoffman (1978) attempted to relate CLI Soil

Capability Classes for Agriculture to crop yields of corn, oats and barley in southern Ontario. He used yield values determined from hand-harvested plots in fields of farms considered to have a high level of management. Mathematical models were developed using multiple regression techniques to relate these yield values to the soil capability classes of each plot, determined from a CLI Soil Capability for Agriculture map drawn at a scale of 1:50 000.

Yields were regressed against capability class, texture, fertility status, and some of the physical and chemical properties of the soils, as well as climatic variables. Stepwise multiple regression revealed a significant direct high correlation between capability class and crop yields. The correlation between yields and soil physical and chemical properties was considerably poorer.

This enabled the formulation of what Hoffman terms "performance indices" for soil classes for common field crops as shown below:

Capability class	Performance index
1	1.00
2	.80
3	.64
4	.49

Class 1 land is assumed to be unity. Class 2 land can be expected to produce 80% of class 1 land, while class 3

land should produce only 64% of class 1 land, and so on.

That these relationships were so well correlated is not unexpected. A good qualitative classification should demonstrate some basis when quantified. The degree of applicability of these performance indices outside southern Ontario is not clear however. In western Canada, CLI classes are based on different crops than their counterparts in eastern Canada. Agro-climatic regions are not yet delineated in sufficient detail throughout the prairie provinces to be compatible with semi-detailed mapping of soil capability similar to that used by Hoffman. Indeed, Peters(1977) found significant yield differences in northern and southern Alberta, on land classed similarly according to the CLI classification system. This indicates either a need for more detailed information concerning climatic limitations in parts of the prairie provinces, or a lack of consistency in the application of the CLI capability classes across the prairies, or both.

The scale of mapping of the capability classification is critical to any attempt to quantify a classification scheme which is qualitative in its application. As scale of mapping becomes larger, a quantification of a qualitative soil ranking such as the CLI classification becomes less useful for the prediction of yields using methods similar to Hoffman's. The application of soil capability classes for

agriculture to detailed soil series information may be more soundly based directly on quantitative yield information, rather than on a qualitative ranking.

D. Quantification of Farm Input Information

Very little work has been undertaken to relate the level of farm inputs necessary to produce crop yields on different soils. Such information is vital to any consideration of the economic worth of these soils. Most commonly, attempts are made to control for farm inputs by assuming a given level of input, or choosing only well managed farms for study. Work by Huffman (1979) in Ontario and Saskatchewan examined farm inputs, yields, capital investment and gross margin per acre in relation to land use systems and CLI Soil Capability Class for Agriculture. Odell (1958) grouped farms studied into four qualitative levels--low, medium, moderately high, and high.

Difficulties inherent in the collection and handling of farm management data have led several workers to circumvent the problem, by using economic criteria to classify the capability of soils. In this way both yield and input factors are considered together. The study by Noble (1965) outlined above is a good example of this type of work. Conklin (1959) described a system of classification of farms in New York State according to expected income of the farmers. Patterson(1975) related gross margin of farming operations to CLI Soil Capability Classes for Agriculture in

southern Ontario. Vink(1960) examined crop input information expressed in monetary units, and found that these varied considerably on various soil types in the Netherlands.

More research is needed in Alberta to obtain quantified, soil specific information on the differences in farm inputs and common farming operations.

III. The Study Area

A. Location

This study covers an area of approximately 500 square kilometers of the western portion of Beaver County (County #9) in east central Alberta (Figure 1). Beaver County is situated 60 kilometers east of the City of Edmonton. The study area is bounded by Tofield to the north, Dodds to the west and Holden to the east.

B. Climate

The entire study area falls within the agro-climatic region designated on the Agro-climatic map of Alberta (Bowser 1967) as class 1, indicating no major climatic limitations to agriculture. Bowser _et al_ (1962) report a mean summer temperature (May to September) of 13.3 degrees, and a mean winter temperature (November to March) of -9 degrees. January is the coldest month, with an average temperature of -14.4 degrees, while July is the warmest, averaging 16.4 degrees. Average frost free period is about 100 days.

Average precipitation for the general area is 430 millimeters per year, with about half falling between June and August. Precipitation is variable. Annual extremes of 230 millimeters and 760 millimeters have been recorded within the last 75 years.

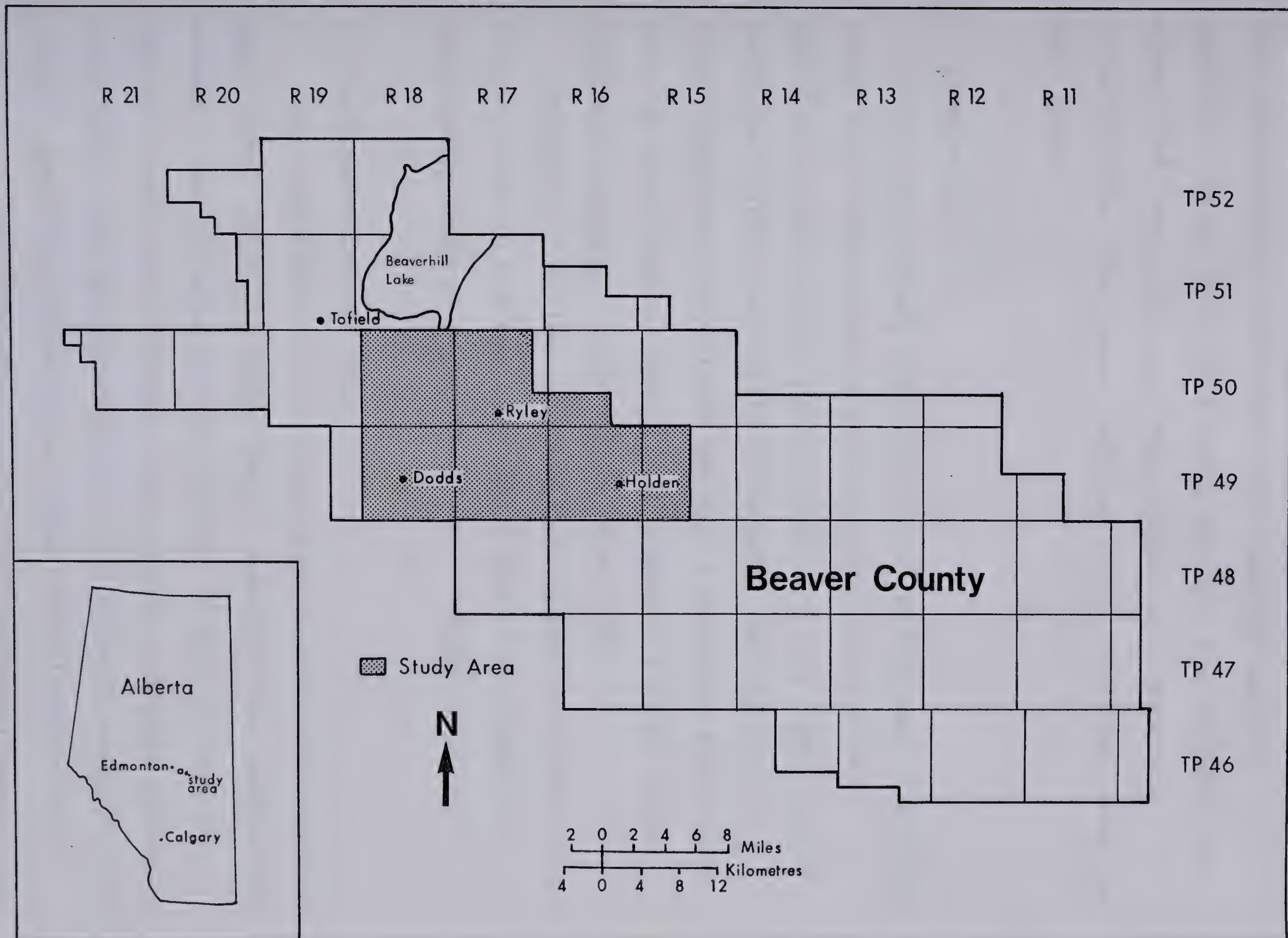

Figure 1. Location of Study area in Beaver County, Alberta.

Meteorological data for the study area is lacking. Long term meteorological stations have been in operation at Camrose, Vegreville, and Viking, but all are outside the borders of the study area. No attempt to extrapolate climatic data from these stations across the study area has been made.

C. Vegetation

The entire study area is located within what Moss(1955) terms the "Grassland-Woodland Ecotone", or Parkland vegetation belt. In its natural state, it is comprised of localized patches or bluffs of aspen trees (Populus tremuloides) and associated shrubs, surrounded by typical prairie grass associations, most commonly a rough fescue (Festuca scabrella) association (Moss 1955).

Almost all of the area has been broken for agriculture at some time in the past, though a few areas have since reverted to natural vegetation, mainly aspen woodland.

D. Topography and Drainage

The topography of the study area is generally level to undulating. It is characterized by many shallow depressional areas, commonly water-filled for all or part of the year. Several broad flat bottomed post-glacial drainage channels exist which can be traced several kilometers. Nowhere in the area is relief sufficiently extreme to be limiting to cultivated crop production, but a few isoloated slopes are

steep enough to be slightly susceptable to soil erosion. The area is drained by Amisk Creek, which empties into Beaverhill Lake to the north.

E. Geology

The south and western portions of the study area are underlain by the sandstones, clays and coal seams of the Edmonton Formation, a brackish water formation of Upper Cretaceous age. To the northwest, the area is underlain by younger Bearpaw shales. Glacial tills derived chiefly from the Edmonton formation cover the entire area (Bowser et al 1962). These generally take the form of gently undulating ground moraine of clay loam texture. Smaller pockets of very dense, sticky basal till can be found in the study area. These consist of Edmonton formation bedrock which has been only very slightly altered by glacial activity. Localized areas of sandy outwash materials, often taking the form of a sandy cappings on low till knolls, are found throughout the area, though most are not mappable at a scale of 1:50 000.

F. Soils and Map Units

Eluviated Black Chernozemic soils and Black Solodized Solonetzic soils dominate the study area. Solonetzic Black Chernozemics and Black Solods are commonly found in topographic association with them. The Eluviated Black soils generally form on the better drained upper topographic positions, while the Solonetzic Blacks, Black Solods, and

Black Solodized Solonetzics are found in topographic sequence down the slopes. Soils in low lying or depressional areas are generally of the Gleysolic order, occasionally associated with Black Solonetzic soils, and gleyed members of the Chernozemic and Solonetzic orders.

The southeastern section of the study area lies within a few kilometers of the boundary traditionally separating "thin" soils (those with an Ah horizon less that 15 centimeters in depth) from "thick" soils (those with an Ah horizon thicker than 15 centimeters). Consequently some "thin" Black Chernozemic and "thin" Black Solodized Solonetz soils exist in the area. Although thickness of Ah horizons has generally been attributed to differences in climate and associated vegetation, many of the soils developed on the dense basal till found in the area have Ah horizons thin enough to fall into the "thin" category. These may be a result of the high salt content and poor structure of the parent material which limit rooting depth.

Although several soil series were recognized in the area, map units based on only three of these were used in the study, because of the location of available crop yield data:

1. Angus Ridge "series" (AGS) is a "thick" Eluviated Black Chernozemic soil, developed on calcareous moderately fine to fine textured till parent material. Some Orthic Black profiles may be included within the Angus Ridge "series" because Ae horizons are commonly mixed with Ah

horizons on cultivated soils and are difficult to distinguish. Topographically, Angus Ridge soils are found on nearly level to gently sloping land;

2. Soils of the Camrose "series" (CMO) belong to the Black Solodized Solonetzic subgroup. They are formed on moderately fine to fine textured calcareous and saline till parent material, and on nearly level to gently undulating topography; and
3. Soils of the Tofield "series" (TOE) are Black Solodic soils, formed on similar parent material and topography to, and generally associated with the Angus Ridge and Camrose "series" soils.

Mapping units used in the study are named after the dominant soil series found in the unit, but are differentiated from one another on the basis of the nature of the association between the dominant and significant soil "series" also found in the unit. For example, an Angus Ridge 5 unit will have dominantly Eluviated and Orthic Black soils with significant Black Solods. An Angus Ridge 6 is similar to the Angus Ridge 5, but has significant Gleysolic soils as well. Map units used in this study are described in Table 1.

G. Present Land Use

Agriculture is the dominant land use in the area. Mixed farming is the most common farm operation. Dairying has been more extensive in the past, but more and more farmers are turning to mixed grain-beef, or grain-hog types of

Table 1. Soil Map Units

Soil Map Unit	Dominant Soil Subgroup	Significant Soil Subgroup
Angus Ridge 5	Eluviated, Orthic	Black Solods
Angus Ridge 6	Black Chernozemics	Black Solods, Gleysols
Angus Ridge 7		Black Solodized Solonetzics, Black Solods, Gleysols
Angus Ridge 8		Black Solodized Solonetzics, Black Solods
Camrose 2	Black Solodized Solonetzics	Gleyed Solodized Solonetzics
Camrose 3		Gleyed Black Solodized Solonetzics, Black Solonetzics, Gleysols
Camrose 4		Solonetzic Blacks, Black Solods
Camrose 5		Solonetzic Blacks, Black Solods, Gleysols
Camrose 6		Eluviated, Orthic Black Chernozemics
Camrose 7		Eluviated, Orthic Black Chernozemics, Gleysols

Table 1. (continued)

Soil Map Unit	Dominant Soil Subgroup	Significant Soil Subgroup
Camrose 8		Eluviated, Orthic Black Chernozemics, Black Solods, "thin" Black Solodized Solonetz.
Camrose 9		Eluviated, Orthic Black Chernozemics, Black Solods, "thin" Black Solodized Solonetz, Gleysols.
Tofield 4	Black Solods	Black Solodized Solonetzics
Tofield 5		Black Solodized Solonetzics, Gleysols

operations. Farmers with specialized operations are in the minority, possibly because the uncertainties of climate and soil render such specialization economically risky.

The area is under some pressure from urban expansion. Tofield, which lies immediately outside the study area, has expanded considerably within the last 5 to 10 years as light industries establish in the area. Other towns in the area, particularly Ryley and Holden could expand similarly in the near future.

Coal mining has been carried out on a small scale near Dodds for many years. A recent proposal by the Calgary Power Corporation to greatly expand this operation over an extensive area near Dodds, would if implemented, change land use patterns considerably in parts of the area. Some oil and gas exploitation has been carried out throughout the region. However, most of these operations consist of small, scattered producing oil and gas wells, which do not alter the dominant land use patterns of the area to any great extent.

IV. General Procedure

A. The Soil Survey

The soil survey information used in this study was collected as part of a soil survey of Beaver County, conducted by the Soils Division, Research Council of Alberta. A combination of aerial photograph interpretation and free field survey was used to delineate soil map units as described in Table 1.

The mapping procedure included the delineation of areas of similar topography, landform, vegetation, and drainage, as accurately as possible, on air photographs at a scale of 1:31 680. These areas were then examined in the field, and identified according to an established legend. Most of the field survey was carried out from May to October 1979, by Mr. R.W. Howitt, and the author. All roads in the area were traversed. Pits were dug using spade and hand auger at least once in every map delineation, to observe and record the physical characteristics of the A, B, and C horizons. In most areas a sequence of pits was dug, to determine the topographic relationships between soils.

Map unit boundaries were altered as required on the basis of this field information, and the units named as outlined in Table 1. The information was then transferred to photomosaics at a scale of 1:50 000.

B. The Data

Hail and Crop Insurance Corporation Crop Yield Information

Approximately 3700 crop yield data records from the study area were obtained from the Alberta Hail and Crop Insurance Corporation, for the years 1968 to 1978. Included with each yield record were data on the amount and type of fertilizers added to the crop, and whether the crop was sown on stubble or fallow land. Most of the pre-1974 records were associated with a section of land (one square mile), while the post-1974 records gave legal locations to the nearest quarter section. Fertilizer addition values were entered into statistical analyses as total pounds of available nitrogen and phosphorus added per acre. These were later converted to kilograms added per hectare.

Only those records meeting the following criteria were used in the statistical analyses:

1. Yield records must be for spring wheat, barley, oats or rapeseed crops, as these are the most commonly grown crops in the area. Only these crops had a sufficient number of yield records to permit statistical analysis;
2. Yield records must be for undamaged crops, as yield reductions due to hail, insects and other damage were considered peripheral to the study;
3. Yield records must be associated with a unique soil map unit. As the average map unit size was considerably less than 1 square mile, much of the pre-1974 data could not

be used. In addition, yield records for quarter sections containing more than one map unit were deleted. However, if for a quarter section containing more than one map unit, only one map unit was cultivated, the yield records were assigned to that map unit; and

4. Yield records must be complete. Records lacking data on fertilizer inputs were deleted.

Additional crop yield information for 1979, similar to the Hail and Crop Insurance Corporation data were obtained directly from farmers during interviews. The final statistical analyses were conducted on a total of 1163 crop yield records, of which:

351 were for spring wheat for the years 1972 to 1979 inclusive:

341 were for barley for the years 1972 to 1979 inclusive;

270 were for oats for the years 1972 to 1979 inclusive; and

201 were for rapeseed, between the years 1977 and 1979.

The Hail and Crop Insurance Corporation yield records included in the study provided yield data for the study area, as shown in Figure 2. Yield records on Camrose and Angus Ridge units were the most numerous not only because these units are the most extensive in the study area, but also because they contain the main cultivated soils. Fewer yield records exist for Tofield units because they are considerably less common in the area. Very few yield records exist for other units such as Kopernic and Killam, as they remain largely uncultivated. A breakdown of the total number

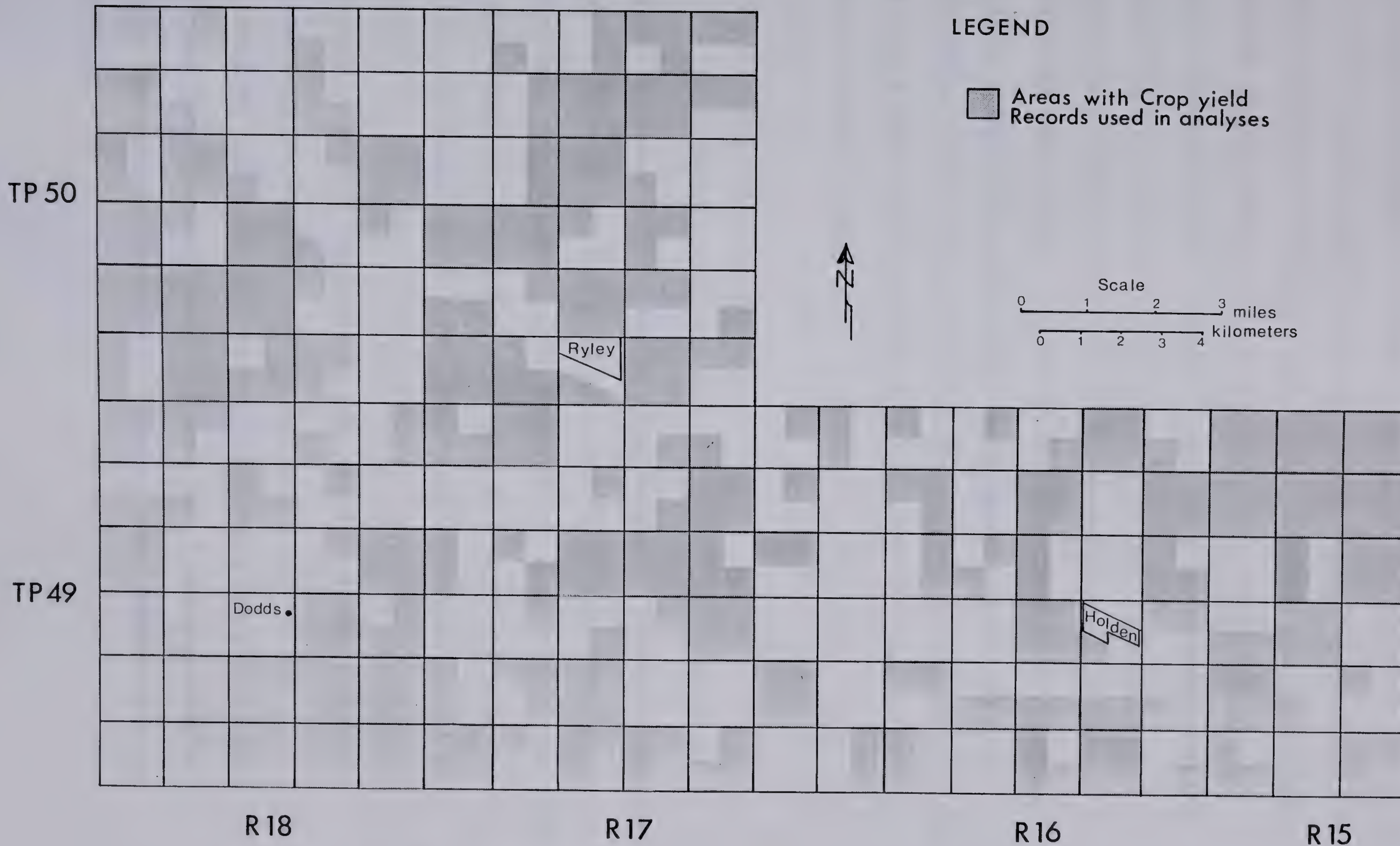

Figure 2. Areas with Crop Yield Records Used in Analyses.

of crop yield records by soil map unit is given in Table 2.

It is recognized that this crop yield information is largely based on farmers' estimates of crop yield, rather than on actual measured yields. As such, there is a wide margin for variation--farmers' accuracy of estimation and reporting of yields, as well as their cultivation and harvesting methods. It must also be noted that yields estimated were yields actually harvested. Where inclement weather conditions prevented the completion of harvest operations, the reduced yields are reported. Generally, the yield estimates were considered accurate to approximately plus or minus 5 bu/A.

C. Questionnaire Information

A questionnaire was administered by the author in October-November 1979, to 93 area farmers. The questionnaire itself, as well as the data derived from the farmer interviews are presented in Appendix 1. An attempt was made to approach all farmers who farmed at least one quarter section of land, the cultivated areas of which could be assigned to a unique soil map unit. This was carried out by means of a letter explaining the nature of the project, followed by a personal visit. Farmers renting and cultivating land for at least three years were included in the questionnaire, although it was not always possible to locate the persons currently farming many rented quarter sections.

Table 2. Number of Crop Yield Records by Soil Map Unit.

	Number of Records by Map Unit			
Map Unit	Wheat	Barley	Rapeseed	Oats
Angus Ridge (all)*	52	36	12	31
Angus Ridge 5	12	11	7	6
Angus Ridge 6	14	10	3	12
Angus Ridge 7	21	25	11	18
Angus Ridge 8	57	62	38	54
Camrose (all)*	94	95	45	16
Camrose 2	11	4	10	18
Camrose 4	28	37	25	50
Camrose 5	39	43	26	42
Camrose 6	3	0	1	1
Camrose 7	13	3	7	11
Camrose 8	8	7	9	14
Camrose 9	2	1	3	1
Tofield 4	1	1	4	3
Tofield 5	6	14	12	8

* Number of crop yield records which could be assigned to the dominant soil series only (Ags or Cmo).

Some farmers grew none of the crops being considered in the study. Others were unwilling to answer the questionnaire in sufficient detail to be useful in the study. Most of the latter farmed land located within the area to be affected by the coal mining operation proposed by the Calgary Power Corporation, and were undoubtedly suspicious of the study. Questionnaire coverage of this area (Figure 3) is therefore less complete than over the area as a whole. No farmer absolutely refused to take part in the interview, and 86 of the 93 questionnaires completed were used in the final data analysis.

The questionnaire was designed to acquire information about the type of operation, farm management practices, general land use, reasons for land use decisions, and relative productivity of land. Additional information concerning the farmer's background, education and future plans for the farm was collected in order to discover any relationships which might exist between these variables and the soils being farmed.

The number of quarter sections with questionnaire information used in the study is summarized in Table 3 by map unit.

Climate Data

As stated above, detailed long term climatic data is completely lacking in the study area. Although meteorological stations do exist at Camrose, Vegreville and Viking, it is not known how precipitation and temperature

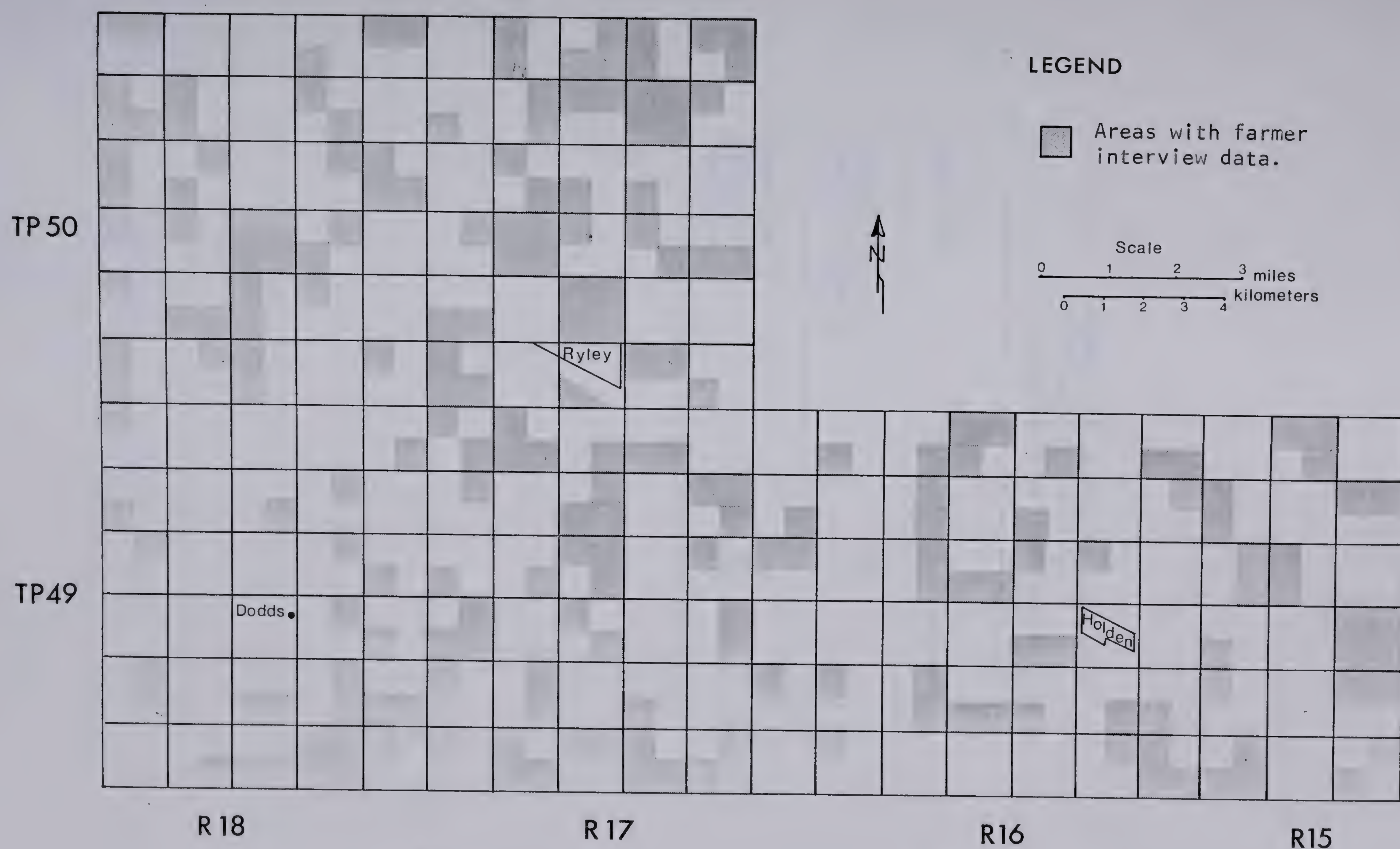

Figure 3. Areas with Farmer Interview Data.

Table 3. Number of Quarter-sections with Questionnaire Information by Map Unit.

Map Unit	Number of Quarters
Angus Ridge 7	18
Angus Ridge 8	41
Camrose 3	16
Camrose 4	27
Camrose 5	35

vary across the study area. A weather station was in operation near Dodds for the period 1976 to 1978, but information was recorded only sporadically, rendering it of limited use in the present study. The Soils Division, Research Council of Alberta established a small temperature and precipitation recording station north of Holden in June 1979. Unfortunately, data did not cover the entire 1979 growing season, and consequently could not be used in the present study.

Indeed, it is difficult to assess which climatic variables to use. Timing of precipitation may be far more critical to crop growth than the total monthly or seasonal precipitation. The temperature variable to be used is also difficult to formulate. Average monthly growing season temperatures are too general to be of use. Total growing degree-days are more specific, but when entered as the temperature variable into Hoffman's(1978) crop yield prediction equations for corn, oats and barley in southern Ontario, they proved insignificant in all cases.

An attempt was made to circumvent these problems of lack of specificity of meteorological data, and choice of representative variables by utilizing non-metric categorical (dummy) variables for each year to account for differences in annual crop yields. For example, crop yield records for year X are assigned the value 1, and all other records 0. Years X1 to Xn would be treated in the same manner. In this way it is possible to enter nominal-scale variables into a

least squares regression equation (Dutta 1975).

D. Analysis of the Data

Analysis of Covariance

For soil map units to be used as a basis for a reliable soil productivity guide it is vital that the crop yield variations within any single map unit be less than that in the population as a whole, and that yield means differ significantly between map units. An analysis of covariance of yields of individual crops on each map unit was carried out to determine if this was the case in the study area.

The crop yield data analyzed were not derived from a balanced experimental design. As conventional analysis of covariance cannot be carried out where cell frequencies are unequal and disproportionate, a least squares regression method, similar to the experimental design analysis method of Overall and Speigel(1969) was used. It estimates the main effects of factors and covariates first, then estimates interaction effects, adjusted for main effects. Overall and Speigel consider this approach most suitable for analysis of variance problems in which main effects are considered more important than interaction effects but where interaction effects may be of some importance. As there is some reasonable expectation that crop response to fertilizer additions could vary on different soils and from year to year, this approach was considered relevent to the present problem.

A packaged programme (Nie *et al* 1975) was used to carry out necessary computations. All tests were carried out at the .10 probability level. This level was considered to be compatible with the estimated nature of the crop yield information. Pounds nitrogen and phosphorus added per acre to the crop were treated as covariates, and later converted to kilograms per hectare. The soil map unit associated with the crop yield and the year of the record were entered as factors, to test the hypothesis that crop yield means on different map units are equal.

Soil map units were also rearranged into groups which could prove to have greater differences in means than the individual map units. The following soil map unit groups were entered as factors in subsequent analyses of covariance:

1. Soil map units, grouped according to the dominant soil series of the unit, were entered as factors. Thus Angus Ridge, Camrose, and Tofield units formed separate groups to determine if mapping units dominated by Chernozemic, Solodized Solonetzic, and Solodic soils differed significantly with respect to crop productivity. This would be equivalent to entering soil map unit information derived from a less detailed soil survey;
2. Camrose units with a significant Black Chernozemic component were separated from those containing Solonetzic components only. It was hypothesized that yield differences due to a significant Black Chernozemic

soil component in a dominantly Black Solodized Solonetzic map unit should occur. Crop yield means for three soil groupings were entered: all Angus Ridge units; Camrose units 2 through 5 inclusive; and Camrose units 6 and 7;

3. Soil map units with a significant Solodic component were grouped with their equivalent unit with significant Solodized Solonetzic soils. It was speculated that the Solodic soils, being of the Solonetz order, should be similar in productivity to Solodized Solonetz soils. Thus four soil map unit groups were distinguished: Angus Ridge 5 and 8; Angus Ridge 6 and 7; Camrose 4 and 6; and Camrose 5 and 7;
4. Equivalent soil map units with and without a Gleysolic soil component were grouped. Since many low lying areas within better drained units, though presently drained and cultivated, still exhibit the morphological characteristics of the Gleysolic Order, it was hypothesized that the presence of Gleysols in a map unit would not necessarily be detrimental to crop productivity. Five soil groups were produced: Angus Ridge 5 and 6; Angus Ridge 7 and 8; Camrose 4 and 5; Camrose 8 and 9; and Tofield 4 and 5.

These groupings are summarized in Table 4.

Only classes containing ten or more crop yield records were included in the analysis of covariance. This resulted in the deletion of some soil map units, or map unit

Table 4. Summary of Soil Map Unit Groups

	Groupings
Groups by dominant soil series	all Angus Ridge units; all Camrose units all Tofield units.
Chernozemic components grouped	all Angus Ridge units; Camrose units 2 to 5; Camrose units 6 & 7.
Solods not distinguished in groups	Angus Ridge 5 & 8; Angus Ridge 6 & 7; Camrose 4 & 6; Camrose 5 & 7.
Groups with significant Gleysols	Angus Ridge 5 & 6; Angus Ridge 7 & 8; Camrose 4 & 5; Camrose 8 & 9; Tofield 4 & 5.

groupings as well as data for some years for each crop record. This gives approximately an 80% chance of detecting a 20% yield difference 90% of the time according to a method given by Sokal and Rohlf (1969). Although not very rigorous, a 20% yield difference was considered adequate given the estimated nature of the crop yield data. As the number of crop yield records increases the per cent yield difference detectable decreases.

A Posteriori Contrast Tests

Although an analysis of covariance indicates that at least one class mean is significantly different from the others, it does not indicate exactly which of the means this might be. Generally, one of several *a posteriori* contrast tests are used to compare the means of classes among themselves. Some of the more widely used of these include Duncan's Multiple Range Test, the Student-Newman-Keuls (SNK) test, and Scheffe's test. All these tests attempt to compare all possible pairs of class means, but differ in the exact computation of the statistic used and the definition of error rate.

Considerable discussion has arisen within the past decade over the applicability and exactness of each of these tests (Chew 1976; Boardman and Moffitt 1971; Baker,1980). A study of type I error (the rejection of a true hypothesis) rates of various *a posteriori* contrast tests was carried out by Boardman and Moffitt (1971).

Duncan's Multiple Range test was shown to be the most

powerful of the three, in that the probability of detecting differences in means is very high. However, the probability of it detecting a difference in means where none in fact exists, is also high. An experiment-wise error rate (the number of experiments with errors divided by the number of experiments carried out) of 38% was found when comparing a series of 10 means at a significance level of .05, using Duncan's Multiple Range Test. However, the comparison-wise error rate (the number of errors divided by the total number of comparisons) for 10 means with a significance level of .05 falls to 2.5%. The test however is not exact for means with unequal replication (Chew 1976, Nie et al 1975).

Scheffe's test proved to be the most conservative of the three in Boardman and Moffitt's study. Its experiment-wise error rate for 10 means at a significance level of .05 is .01%. On a comparison-wise basis, the error rate rises to approximately .2%. It is however, less likely than Duncan's Multiple Range Test to discern differences in means where they do exist. Unlike Duncan's Multiple Range Test, it is exact for means with unequal replication.

The Student-Newman-Keuls test (SNK) is considerably more powerful than Scheffe's test, yet holds the experiment-wise error rate to 5% for 10 means tested at a significance level of .05. It remains less powerful than Duncan's Multiple Range Test, and has the added disadvantage of being inexact for means with unequal replication.

The choice of an a posteriori contrast test is not

easy. Chew (1976) suggests, after an extensive review of the subject, that

> "the last word has not been written on the choice of a multiple comparison procedure"

He recommends the use of Duncan's Multiple Range Test where it is the comparison-wise error rate which is of concern, as in this study. Since a probability level of .10 has been used to test the analysis of covariance a comparison-wise error rate of 2.5% is acceptable. Considering the nature of the crop yield data, its variability, and the number of variables affecting crop yield which cannot be measured, the increased power of Duncan's Multiple Range Test over the other two tests was thought to be desirable. Similarly, inexactness due to unequal replication among means will not likely affect results significantly. Duncan's Multiple Range Test, at a probability level of .10 was therefore carried out wherever main effects due to soils proved significant at the .10 level using analysis of covariance as described above.

Least Squares Regression Analysis

Least-squares multiple regression techniques were used to investigate the following:

1. The effect of soils, as described by soil map units and groupings of map units on crop yield variation; and
2. The relative reliability of using soils as described by soil map units as predictors of crop productivity.

A partially saturated linear yield prediction model (Model 1) was set up, of the form:

$$Y=A+B1X1+B2X2+B3E1+B4E2+B5D1+B6D2+B7(X1D1)+B8(X1D2)$$
$$+B9(X2D1)+B10(X2D2)+B11(E1D1)+B12(E1D2)+B13(E2D1)+B14(E2D2)$$

where:

Y=yield (bushels/acre)

X1 & X2 =total available nitrogen and phosphorus added (lb/A);

D1 & D2 =dummy variables set up to account for yield differences between map units and groups of map units;

E1 & E2 = dummy variables set up to account for yield differences between years;

A = the regression constant;

B1 to B14 = the regression coefficients.

The soil management variable--whether the crop was sown on fallow or stubble land--was initially included, but was excluded in the final analyses because of a high degree of multicollinearity between it, and rates of fertilizers added. Since farmers in this area generally apply different rates of fertilizers to stubble as opposed to fallow land, the fertilizer variables, and the fallow-stubble variable are essentially measures of the same phenomenon. Little if any information is lost in deleting the variable.

The phosphorous rate variables for wheat, barley, and rapeseed followed normal distributions. Logarithmic transformations were performed on the nitrogen rate variable for all four crops, and on the phosphorous rate variable for

oats to normalize their distributions, a pre-requisite for least squares regression.

Three multiple regression models were run using the Statistical Package for Social Sciences (SPSS) multiple regression procedure (Nie _et_ _al_ 1975):

1. The partially saturated model outlined above;
2. The same model without interaction terms of the form:

   $$Y=A+B1X1+B2X2+B3E1+B4E2+B5D1+B6D2;$$ and

3. The model with neither interaction terms, nor dummy variables representing map units or groups of map units of the form:

   $$Y=A+B1X1+B2X2.$$

In this way the predictive power of soil and interaction terms could be evaluated.

Multicollinearity again proved to be a problem when running some of the partially saturated models, where an interaction term was highly correlated to one of its component variables. In such a case, the interaction term was dropped. Most of the explaining power of the interaction term is accounted for by the component variables. Again, little if any information is lost in deleting the interaction term, and problems of widely fluctuating regression coefficients, and incorrect evaluation of the relative importance of the independent variables associated with multicollinearity are avoided.

Farm Input Information Analysis

The farm input information was derived entirely from

the questionnaire administered to area farmers as described above. The questionnaire and data are presented in Appendix 1. This information was analyzed statistically using either analysis of covariance procedures, or contingency Chi-square, depending on the nature of the data.

Farmers' estimates of time and fuel required to cultivate each quarter section of land were analyzed using analysis of covariance as outlined above. Time and fuel consumption were entered into separate analyses, as the dependent variables. Horsepower of tractor and width (in feet) of cultivator used were entered into each as independent cofactors. Time and fuel consumption variables were then combined into a new variable, created by dividing fuel consumption by time. The result--fuel requirements per hectare--was subjected to analysis of covariance as well, again with machinery size variables as covariates. Duncan's Multiple Range Test was used as an a posteriori test for all three analyses of covariance. A probability level of .10 was again utilized.

Chi-square contingency tables were used to test the hypothesis of independence between soil map units, and various management and demographic factors (Dixon and Massey 1969). This method allows for example, the testing of whether complete crop failure occurs with equal frequency on all map units, or whether it is more common on some.

Chi-square contingency was used to test the following hypotheses, at a probability level of .10:

1. The percentage of a quarter section left in summerfallow is independent of soil map units;
2. The number of field passes used to produce grain and rapeseed and to work summerfallow are independent of map units;
3. Soils are no more likely to be considered important in making crop rotation decisions in some map units than in others;
4. Soils of some map units are not more likely than others to increase the time required in cultivation, or to create other problems for the farmer;
5. Percentage of years in which crop failure occurred because of either excessively wet or dry conditions is independent of soil map units; and
6. Size of farm, the farm's main income producing product, whether or not the farm will remain in the family, the state of farm buildings and house, and the age group of the farmer are all independent of soil as described by soil map units.

V. Results and Discussion

A. Crop Yield Data Analysis

Analyses of Covariance

The results of analysis of covariance testing for each crop on individual soil map units is given in Table 5. The hypothesis of equal means of yields of wheat on 7 soil map units could not be rejected at the .10 level of significance. No conclusions can be drawn.

For the other three crops however, the hypothesis of equal means could be rejected. No single map unit could be separated from all the others as having significantly different yield means using Duncan's Multiple Range Test. For barley, the Angus Ridge 8 unit proved to have a significantly higher yield mean than Camrose 4 and 5 and Angus Ridge 7 units, which could not be separated from one another. The barley yield mean on Tofield 5 could not be separated from either these units or Angus Ridge 8.

Yield means for rapeseed on Camrose 5 was significantly lower than on Angus Ridge 7 and 8 units. Yield means on Angus Ridge 7 and 8 units could not be separated from one another, nor could their yields, nor yields on the Camrose 4 unit be separated from yields on the Camrose 5 unit.

Results of Duncan's Multiple Range Test for oats showed the Angus Ridge 8 map unit to have a significantly higher yield mean than either Angus Ridge 7 or Camrose 5, though the latter two could not be separated from one another.

Table 5. Results of Analysis of Covariance and Duncan's Multiple Range Tests for Soil Map Units.

Crop	Degrees of freedom	F	Signif. of F	*	Yield Means of Units after adjusting for fertilizer additions and year. Map units	Mean Kg/ha	N
Wheat	6	1.601	.154		Cmo 7	1650	13
					Ags 8	2055	31
					Cmo 5	2068	29
					Ags 6	2078	16
					Cmo 4	2163	26
					Ags 7	2203	21
					Cmo 2	2380	10
Barley	4	2.224	.071		Cmo 5	1920	34
					Ags 7	2000	20
					Cmo 4	2069	33
					Toe 5	2083	13
					Ags 8	2471	39
Rapeseed	3	2.531	.065		Cmo 5	835	21
					Cmo 4	940	21
					Ags 8	1031	28
					Ags 7	1038	10
Oats	5	1.988	.084		Ags 7	2451	12
					Cmo 5	2741	38
					Cmo 2	2798	15
					Cmo 4	3077	47
					Cmo 8	3091	10
					Ags 8	3228	43

* Groups with homogeneous means according to Duncan's Multiple Range Test are joined.

Camrose 2, 4, and 8 map units were members of both groups.

It is most difficult to establish any kind of a productivity rating for any of these crops based on these results. Yield differences do exist, but they are not consistent. The Angus Ridge 8 unit has the highest yield for barley and oats, but not for rapeseed. The Camrose 5 unit has the lowest yield for rapeseed and barley, but not oats. The highest rapeseed yield mean occurred on the Angus Ridge 7 unit, while the lowest yield mean for oats was on the same unit. This is difficult to explain in view of the yield differences intuitively expected on soils of the Black Solodized Solonetzic and Black Chernozemic subgroups. Several hypotheses must be considered:

1. Soil map units as mapped at the semi-detailed level do not adequately delineate areas of equal crop productivity;
2. Differences in crop yields between individual map units are too small to be distinguishable, given the limitations of the crop yield data collection methods;
3. Farmers may have managed to adapt their general farming practices on these Solonetzic soil units so well, that they are not much less productive than the Chernozemic soils.
4. Productivity differences between Black Solodized Solonetzic and Black Chernozemic soils in the area are considerably less than would be expected.

When soil map units were grouped together on the basis of dominant soil series (Table 6), a more uniform pattern emerged. The hypothesis of equality of means was rejected for all crops except oats, although rapeseed was a borderline case. Duncan's Multiple Range Test was able to distinguish yield means of wheat, barley, and rapeseed on Angus Ridge units from those on Camrose units. Tofield units could not be separated from either the Camrose or Angus Ridge units in any case.

Relative productivity of soil series groups can be roughly ranked if the ambiguous position of the Tofield map units is not considered. Barley and rapeseed grown on dominantly Camrose soil map units both produced 89% of the yield of the same crops grown on dominantly Angus Ridge soil map units. Wheat grown on dominantly Camrose soil map units produced 93% of the yield of dominantly Angus Ridge map units. No significant difference could be found between oat yields grown on dominantly Camrose and Angus Ridge map units.

These results are compatible with the relative sensitivities of these crops to Solonetzic soil conditions. Rapeseed and barley, being the most sensitive of the four crops to adverse soil moisture conditions brought about by the poor structure of the Solonetzic B horizon, exhibited the greatest yield reduction of all on the Camrose units. Oats, being most tolerant, did not suffer any significant crop yield reduction at all. The inability of Duncan's

Table 6. Results of Analysis of Covariance and Duncan's Multiple Range Tests for Soil Series Groups.

Crop	Degrees of freedom	F	Signif. of F	*	Yield means of groups after adjusting for fertilizer additions and year: Map group	Mean Kg/ha	N
Wheat	1	3.778	.053		Cmo units	1946	163
					Ags units	2086	113
Barley	2	2.901	.057		Cmo units	2003	147
					Toe units	2108	16
					Ags units	2250	96
Rapeseed	2	2.326	.101		Cmo units	888	100
					Toe units	984	15
					Ags units	995	57
Oats	2	2.225	.109		Ags units	2997	121
					Cmo units	2771	266
					Toe units	2740	14

* Groups with homogeneous means according to Duncan's Multiple Range Test are joined.

Multiple Range Test to distinguish Tofield yields from either Camrose or Angus Ridge yields may be a function of the considerably smaller number of observations for Tofield units. Alternatively, it could indicate that the Tofield units encompass a range of productivity similar to both of the other soil series groups.

The relative consistency of results of testing of yields on soil map units grouped according to dominant soil series, allows the elimination of hypotheses 3 and 4 presented above to explain the lack of significance of most map units:

1. Productivity differences do exist between these Black Chernozemic and Black Solodized Solonetzic map units; and
2. Farmers have not entirely eliminated yield differences with management practices.

It could also be indicative of the larger body of crop yield data available for each soil series group than for individual map units.

Analysis of Covariance results of crop yield means were less significant when Camrose map units with a significant Black Chernozemic component were grouped separately from those containing soil of the Solonetz subgroup only (Table 7). No groups of rapeseed and oat yield means proved to be significantly different from one another. Analysis of covariance results were significant for wheat and barley only.

Table 7. Results of Analysis of Covariance and Duncan's Multiple Range Tests for Chernozemic Components Grouped.

Crop	Degrees of freedom	F	Signif. of F	*	Yield means of groups after adjusting for fertilizer additions and year. Map group	Mean Kg/ha	N
Wheat	2	5.673	.004		Cmo 6 & 7	1538	15
					Cmo 2 TO 5	2046	72
					Ags units	2093	113
Barley	1	5.091	.025		Cmo 2 TO 5	1964	79
					Ags units	2257	93
Rapeseed	1	2.492	.118		Cmo 2 to 5	888	53
					Ags units	989	55
Oats	2	1.045	.345		Cmo 6 & 7	2703	12
					Cmo 2 to 5	2845	112
					Ags units	3014	96

* Groups with homogeneous means according to Duncan's Multiple Range Tests are joined.

For wheat, Duncan's Multiple Range Test separated the Camrose 6 and 7 grouping as having a significantly lower mean yield than either the Camrose 2 to 5 group or the Angus Ridge group. It was unable however to distinguish between yield means on the Camrose 2 to 5 group and those on the Angus Ridge group.

This result is unexpected. One would intuitively expect the Chernozemic component of the Camrose 6 & 7 group to increase yields, not decrease them. The Camrose 6 & 7 group could not be entered into the analysis of covariance for barley yields because of an insufficient number of yield records for these soil map units. However, the removal of Camrose units with a Black Chernozemic component resulted in an increase in the significance level of the analysis of covariance from that of the soil series groups. This may indicate that yields on the Camrose 2 to 5 group are more homogeneous than yields from the Camrose soil series group as a whole.

Results of this set of tests are confusing. It is difficult to explain why the Camrose 6 & 7 soil map units should have significantly lower yields of wheat than the Camrose 2 to 5 map unit group. It is even more surprising that yields on the Angus Ridge soil map unit group were not significantly different from the Camrose 2 to 5 group in view of the results of testing on soil series groups. This may be a result of the relatively small number of observations on the Camrose 6 & 7 group. There is no

evidence to show that Black Solodized Solonetzic units without a Black Chernozemic component (Cmo 2 to 5) have significantly different yields than Black Solodized Solonetzic units with a Black Chernozemic component (Cmo 6 & 7). Yield mean distinctions were generaly poorer on these groups than on soil map units and soil series groups. Consequently, it is difficult to draw any conclusions from these results.

The grouping of soil map units with a significant Black Solodic component with their equivalent Black Solodized Solonetzic map unit produced a significant analysis of covariance test for oat yields only (Table 8). In this case, Duncan's Multiple Range Test was able to distinguish two significantly different subsets of group means. Oat yields on Angus Ridge 6 & 7 units and Camrose 5 & 7 units were considered homogeneous, with significantly lower yields than those on Camrose 4 & 6 units, and Angus Ridge 5 and 8 units. The latter two groups were also found to be homogeneous.

Each of these two homogeneous subsets of map unit groups have Black Chernozemic, Black Solodized Solonetzic and Black Solodic components. They differ only in that one contains a significant Gleysolic component and the other does not. The possibility exists that oats are more intolerant of poorly drained soil conditions than of Black Solodized Solonetzic soil characteristics. This may explain why map units grouped into separate Black Solodized Solonetzic and Black Chernozemic groups did not have

Table 8. Results of Analysis of Covariance and Duncan's Multiple Range Tests for groups--Solods not distinguished.

Crop	Degrees of freedom	F	Signif. of F	Yield means of groups after adjusting for fertilizer additions and year: Map group	Mean Kg/ha	N
Wheat	3	.696	.556	Cmo 5 & 7	1938	42
				Ags 6 & 7	2054	31
				Cmo 5 & 8	2073	37
				Cmo 4 & 6	2093	28
Barley	3	1.929	.128	Cmo 5 & 7	1898	37
				Cmo 4 & 6	2056	33
				Ags 6 & 7	2138	28
				Ags 5 & 8	2365	45
Rapeseed	3	2.078	.110	Cmo 5 & 7	877	27
				Cmo 4 & 6	939	22
				Ags 5 & 8	1022	34
				Ags 6 & 7	1036	12
Oats	3	5.388	.001	Ags 6 & 7	2502	23
				Cmo 5 & 7	2700	56
				Cmo 4 & 6	3015	51
				Ags 5 & 8	3313	52

* Groups with homogeneous means according to Duncan's Multiple Range Test are joined.

significantly different yield means for oats using analysis of covariance (Table 6). They would differ only when grouped into poorly drained and better drained groups. The level of significance of .634 obtained when analysis of covariance was carried out for oat yields on soil map unit groups which included units with and without Gleysols (Table 9), is further evidence of this. Map groups with significant Gleysolic component produced only 83% of the yield of groups without the Gleysols.

Finally, when equivalent soil map units with and without a Gleysolic component were grouped together for analysis of covariance testing, wheat and rapeseed yield means were significantly different (Table 9). For wheat yields, Camrose 6 & 7 units were shown to produce significantly less than any of the other groups tested, including the Camrose 4 & 5 group, using Duncan's Multiple Range Test. As proved to be the case when Camrose map units with a significant Black Chernozemic component were grouped separately from those without, it is difficult to theorize why crop yields on the Camrose 6 & 7 soil map unit groupings for wheat should be significantly less than all other groups, including Camrose 4 & 5.

Duncan's Multiple Range Test was able to distinguish between rapeseed yield means produced on Camrose 4 & 5 units, and those produced on Angus Ridge 7 & 8 units. Yields on Tofield 4 & 5 units could not be distinguished from either the Camrose 4 & 5, or the Angus Ridge 7 & 8 groups.

Table 9. Results of Analysis of Covariance and Duncan's Multiple Range Test for groups with significant Gleysols.

Crop	Degrees of freedom	F	Signif. of F	*	Yield means of units after adjusting for fertilizer additions and year. Map group	Mean Kg/ha.	N
Wheat	3	2.358	.075		Cmo 6 & 7	1652	15
					Ags 7 & 8	2091	52
					Cmo 4 & 5	2096	55
					Ags 6 & 7	2159	15
Barley	3	1.481	.223		Ags 5 & 6	1988	67
					Ags 7 & 8	2308	59
					Cmo 4 & 5	1988	67
					Toe 4 & 5	2061	14
Rapeseed	2	3.197	.046		Cmo 4 & 5	890	42
					Toe 4 & 5	957	10
					Ags 7 & 8	1034	38
Oats	4	.641	.634		Ags 5 & 6	3077	79
					Ags 7 & 8	2886	91
					Cmo 4 & 5	3144	10
					Cmo 6 & 7	2765	12
					Cmo 8 & 9	2917	14

* Groups with homogeneous means according to Duncan's Multiple Range Tests are joined.

The level of significance of the analysis of covariance is increased for these groups over the soil series groups. This indicates that yields on Camrose 4 & 5, and Angus Ridge 7 & 8 groups are more homogeneous than those on the equivalent soil series groups. These groupings do not appear to represent areas of equal crop productivity as well as the soil map units themselves, and the groupings by dominant soil series.

To summarize, these points may be made:

1. Only the groupings of soil map units according to dominant soil series appear to delineate areas with yield means of wheat, barley, and rapeseed which are significantly different from one another to such an extent that a rough estimate of the relative productivity of the groups can be made;
2. Soil drainage conditions may affect oat yields more than dominant soil subgroup in this area. It may be more realistic to consider soil drainage conditions in a productivity rating for oats as well as dominant soil subgroup;
3. Regrouping of map units produces no improvement in the significance of yield mean differences over the dominant soil series grouping, except for oats;
4. The hypothesis that soil map units as mapped at the semi-detailed level do not adequately delineate areas of equal crop productivity, cannot be rejected in view of the results of analysis of covariance and Duncan's

Multiple Range Test tests presented here;

5. The hypothesis that differences in yields between soil map units are too small to be discerned with the crop yield data used in this study cannot be rejected.

Least-squares Regression Analyses

Coefficients of determination (R-square values) obtained from least-squares regression analyses are given in Table 10. The coefficient of determination indicates the proportion of variation observed in the dependent variable which can be explained by variation in all the independent variables. In the case of wheat with all soil map units as independent variables for example, 46% of the yield variation can be explained by the variation in the independent variables--fertilizers added, year, soil map units, and soil-year interactions (Model 1). Model 2, run without soil map unit-year interaction terms, was able to account for 34% of wheat yield variation. When no terms were included for soils--neither map units nor soil-year interactions terms--only 29% of the variation in wheat yield could be explained by the remaining fertilizer and year variables (Model 3). Thus, 12% of the yield variation can be accounted for by the interaction variables, and 5% by the soil map unit variables. A total of 17% of the yield variation of wheat can be explained either directly by variation in soil map units, or indirectly by variation in soil-year interaction terms.

R-square values of Model 1 for all crops and different

Table 10. Results of Least-squares Regression Analysis. R-square Values*

Map Group	Crop	R-square *Model 1	R-square *Model 2	R-square *Model 3	Yield variation due to 1-2 inter-action only	1-3 soil+ inter-action	2-3 soil only
Map units	wheat	.46	.34	.29	.12	.17	.05
	barley	.64	.59	.56	.05	.08	.03
	rape	.43	.32	.25	.11	.18	.07
	oats	.67	.61	.59	.06	.08	.02
Dominant soil series grouping	wheat	.42	.40	.40	.02	.02	.00
	barley	.60	.59	.58	.01	.02	.01
	rape	.26	.22	.20	.04	.06	.02
	oats	.58	.56	.55	.02	.03	.01
Signif. Chernozemic component	wheat	.50	.46	.43	.04	.07	.03
	barley	.56	.56	.54	.00	.02	.02
	rape	.23	.21	.19	.02	.04	.02
	oats	.59	.56	.55	.03	.04	.01
Solods not distinguished	wheat	.44	.39	.38	.05	.06	.01
	barley	.60	.56	.54	.04	.06	.02
	rape	.40	.31	.27	.09	.13	.04
	oats	.51	.47	.44	.04	.07	.03
Groups with Gleysols	wheat	.48	.41	.38	.07	.10	.03
	barley	.60	.56	.54	.04	.06	.02
	rape	.39	.30	.25	.09	.14	.05
	oats	.58	.51	.51	.07	.07	.00

* All R-square values were significant at a probability level of .01 and .10.
*Model 1. Partially saturated model, with soil, year and soil-year interaction terms.
*Model 2. Model 1 without interaction terms.
*Model 3. Model 1 without soil, year and interaction terms.

soil map unit groupings vary from .67 to .23. Although not high, they are compatible with R-square values reported by Odell (1958) and Rust and Odell (1957), who recorded R-square values ranging from .18 to .56 for corn and soybean yields on various soils, using yield data derived from farmers' records. They entered variables for temperature and precipitation, fertilizers added, cropping system, and year into their models. Soil was not entered as a separate variable. A series of models for yield records on different soils was generated.

Of the four crops, barley generally has the highest R-square values for Model 1. These vary from .64 when soil map units were entered into the equation, to .56 when soil map groups with separated Chernozemic components were entered.

Rapeseed had by far the lowest of the R-square values for Model 1, which ranged from .43 for soil map units themselves, to .23 for map groups with separated Chernozemic components. Wheat however, had a maximun R-square of .50 where soil map units with Chernozemic components were entered, and a minimum of .42 when soil series groups were entered. Oats had a maximum of .67 when soil map units were entered, and a minimum of .58 for soil series groups.

All these values decrease to varying degrees when models were run without interaction and soil variables (Models 2 and 3). Column 5 of Table 10 (yield variation due to Model 1 minus Model 3) indicates the increase in R-square

value when soil and soil-year interaction terms were included. These values represent the variation in crop yield which can be accounted for by variation in soils and soil-year interaction terms. These were obtained by subtracting the R-square value of the partially saturated model from the R-square value of the model run with neither soil nor soil-year interaction terms.

Models run with soil map units consistently produced the highest proportion of variation explained by soil and soil-year interaction variables. Groups based on map units with a significant Gleysolic component included with their equivalent map units without Gleysols were second highest. Dominant soil series groupings appear to have the lowest R-square values associated with soil and soil-year interaction terms. Soil map units then appear to be slightly better predictors of crop productivity than any of the other groupings. However, with only 8% to 18% of yield variation explainable by soil map units and interaction terms, yield predictions cannot be based on soil map units alone. Use of any of the other soil map unit groupings for crop yield predictions will be even less satisfactory.

In most cases, more yield variation was accounted for by soil and soil-year interaction variables for rapeseed than for any other crop. This is most likely a reflection on the higher sensitivity of this crop to Solonetzic soils.

Sixty to seventy per cent of the change in R-square values due to soil and soil-year interactions (Models 1 - 3)

for barley and rape is a result of the interaction terms without soil variables, as opposed to only 30% to 40% for wheat and oats (Models 1-2/Models 1-3). This may indicate that soil-year interactions are more important on the former. The higher sensitivities of barley and rapeseed to adverse soil moisture conditions could significantly alter yields of these crops in excessively moist or dry years, where wheat and oats remain relatively unaffected.

In summary, several points can be made:

1. Soil map units appear to be slightly better predictors of crop yield variation than any of the other groupings;
2. Soil map units grouped with the Gleysolic component and groups where Solods were not distinguished, were poorer;
3. The other two, dominant soil series groups and groups with separated Chernozemic components were the poorest predictors of crop yield variation;
4. Extreme caution should be exercised in using either soil map units or any of the soil map unit groupings for prediction of crop yields, as the proportion of yield variation explained by soil and soil-year interaction variables is very low in all cases;
5. Fertilizer additions and year variables account for most of the yield variation.

It must be noted that R-square values will increase with the addition of interaction terms into the regression equation no matter how small the actual interaction effect. Part or all of the higher R-square values due to soil and

soil-year interactions on soil map units may in fact be a result of the larger number of variables entered into these models.

B. Analysis of Farm Input Information

General Information

The questionnaire administered to farmers in the study area contained a number of questions designed to characterize the kinds of farms and farming operations in the area, and the background of the farmers themselves. The questionnaire and data acquired are given in Appendix 1. Examination of the results indicated that the average farm size was about five quarter sections of land, although they ranged in size from one quarter section, to sixteen quarter sections. Thirty-five per cent of the farmers surveyed reported grain to be the main income producer of their farms, while 27% reported grain and livestock to produce equal incomes. Dairy and beef operations made up about 15% each of all operations surveyed. Hog, chicken and egg operations made up the remainder. None reported the use of any special techniques or ameliorative practices, such as minimum tillage, ripping, or deep plowing.

Few of the farmers had had any formal agricultural training. Only 5% reported a university or college education. Another 5% had made use of university, college, or Department of Agriculture extension courses.

Thirty-five per cent of the farmers fell within the

45-55 years age group. The age distribution around this group was approximately symmetrical: Ten per cent were under 35; 22% between 35 and 45; and 33% were over 55 years of age.

Sixty-six per cent had no plans for expanding their farm operations within the next ten years, either because they were satisfied with the present size of their farms, or because they felt they would be unable to expand. Of the 24% who had definite plans for expansion, most fell into the younger age groups. Ten percent were undecided. Fifty-two per cent of farmers thought the farm would stay in the family when they retired, although another 42% did not know.

Results of Chi-square contingency table testing of this information, where it was possible to carry out, are given in Table 11. No significant relationships between soil map units and size of farm, main farm income producers, age group of farmer, plans for farm expansion, or the possibility of the farm remaining in the family, could be found. It appears that soils, as described by soil map units do not exert a great deal of influence on the type or size of farm operations, or the farmer's plans for the future.

A qualitative assessment of the condition of farm buildings and house was made at the time of the interview. Buildings were subjectively classed into two groups: below average to average, and above average. It was hypothesized that this could reflect farm income, which in turn should be a function of the relative productivity of the soils being

Table 11. Results of Chi-square Testing of Farmer Information. Level of significance=.10.

Variable	Chi-square value	Degrees of freedom	Results
Size of farm	3.67	8	Cannot reject hypothesis of independence of farm size and soil map units.
Main farm income producer	18.31	12	Cannot reject hypothesis of independence of main farm income producer and soil map units.
Farm expansion	4.40	4	Cannot reject hypothesis of independence of farm expansion and soil map units.
Farm stays in family	1.64	5	Cannot reject hypothesis of independence of farm staying in present farmer's family, and soil map units.
Age group of farmer	7.36	9	Cannot reject hypothesis of independence of age group of farmer and soil map units.

farmed. Farm building ratings were assigned to all soil map units included in the study. Thus buildings from a farm which reported information from one Angus Ridge 7 unit, and one Camrose 5 unit would be associated with both map units, and would be entered into analyses twice. It must be acknowledged that income from non-farm sources may be important in determing the state of buildings. This has not been included in the study.

Results of Chi-square contingency table testing appears in Table 12. There appears to be some relationship between the state of the farm house, and soil map units of the farm, but not between the state of the farm buildings and soil map units. Condition of farm buildings may bear more of a relationship to the type of farm operation than to soil productivity.

An examination of deviations of observed from expected frequencies derived from the Chi-square contingency table for the state of the farm house, is shown in Table 13. Houses on farms with Black Chernozemic Angus Ridge 7 soil map units are more likely to be above average, while those with Black Solodized Solonetzic Camrose 3 and 5 units are more likely to be average or below average. This may reflect a difference in soil productivity, as it is difficult to justify an alternate hypothesis.

Land Use Information

The most common crop rotation followed in the area is rapeseed on summerfallow, followed by wheat and barley or

Table 12. Results of Chi-square Testing of Farm Input Data. .01 level of significance.

Variable	Chi-square value	Degrees of freedom	Results
State of farm buildings	3.90	4	Cannot reject hypothesis of independence of state of farm buildings and soil map units.
State of farm house	9.27	4	Must reject hypothesis of independence of state of farm house and soil map units.

Table 13. Deviations From Expected Frequencies. State of Farm House.

State of house	Ags 7	Ags 8	Cmo 3	Cmo 4	Cmo 5
Average or below average	-5.9	+0.8	+3.3	-0.4	+2.1
Above average	+5.9	-0.8	-3.3	+0.4	-2.1

oats in subsequent years. Only a few farmers reported regularly incorporating several years of grass or legumes into their rotation systems. Less than 15% of them reported soil characteristics as being important in deciding upon what crop rotation system would be used in a given quarter section of land. Fourty-five per cent of farmers used a three year rotation--two years of crops followed by one of summerfallow. Twenty-five percent summerfallowed one year in four, and about 16% used continuous cropping.

The following hypotheses were tested, using Chi-square contingency tables:

1. The percentage of time a quarter section of land remains in summerfallow is independent of the soil as described by the soil map unit of that quarter section; and
2. Farmers are no more likely to consider soil characteristics of some map units than others, when selecting a crop rotation system.

Results are given in Table 14. No relationship between the actual crop rotation and soil map units, and the importance of soils in making crop rotation decisions and soil map units could be found. The soil as described by soil map units does not appear to determine whether or not a farmer considers soil characteristics when deciding upon crop rotation. Nor does it affect the percentage of time land is left in summerfallow. Most farmers actually varied their crop rotation systems very little from field to field, and year to year. Variations in a rotation scheme were more

Table 14. Results of Chi-square Testing of Crop Rotation. Level of significance=.10

Variable	Chi-square value	Degrees of freedom	Results
% of farm in fallow	6.62	6	Cannot reject hypothesis of independence of % of farm in fallow, and soil map units.
Soils important in crop rotation.	2.89	3	Cannot reject hypothesis of independence of the importance of soils in crop rotation and soil map units.

often the result of weather or soil moisture conditions before and at seeding time.

Many factors other than soil entered into farmers' decisions on land usage. Several semi-retired farmers for example, kept most of their farms in pasture, simply because they were no longer able to manage a full scale operation. The soils certainly could have been profitibly cultivated, and had been in the past. Almost all dairy farmers kept the quarter section nearest the farm buildings in pasture for convenience, regardless of the soil characteristics. Most knew that the soil could be profitably cultivated, but felt that the pasture was necessary for their operations.

One farmer with a purebred cattle operation did not base his land use decisions on soil characteristics at all. Accessibility, location with respect to neighbours' cattle, and state of fencing of pastures dictated which areas remained in pasture, and which were cultivated. Again, he was well aware that many of the soils under pasture would be very productive if cultivated, but as a specialized operator, he was not interested in commercial grain production. Similarly, operators specializing in grain production alone tended to cultivate marginal soils, as they had little use for pasture land.

<u>Farm Input Information</u>

Time and fuel requirements for cultivation of soil map units were considered to be important in assessing the relative productivity of soil map units for the purposes of

this study. Two soil map units cannot be considered of equal productivity if one requires greater inputs of time (labour) and fuel to produce a crop than the other. These variables, and a combination of them, which estimated the amount of fuel required to cultivate a unit area of a map unit were subjected to analysis of covariance and Duncan's Multiple Range Test (Table 15). Means of time requirements per hectare, fuel consumption per hour, and fuel requirements per hectare to cultivate soils of different map units differ significantly. Duncan's Multiple Range Test showed Angus Ridge 7 units to require significantly less fuel to cultivate than the other units. It could not separate means on Angus Ridge 8 units from those on the Camrose units. Camrose 4 and Angus Ridge 7 units required sigificantly less time to cultivate than Camrose 5 units. The position of the Angus Ridge 8 unit remains uncertain here as well. Means cannot be distinguished from either group.

When these two variables were combined to form a fuel requirements/hectare variable, the level of significance of the analysis of covariance increased. Again, the Angus Ridge 7 unit required the least fuel to cultivate one hectare. Angus Ridge 8 units required somewhat more,while Camrose 5 units required more fuel than any of the others. The position of the Camrose 4 unit was ambiguous, as it could not be separated from the Angus Ridge units.

These results indicate a definite difference in fuel and time requirements for cultivation of different soil map

Table 15. Results of Analysis of Covariance for Fuel and Time Requirements.

Source variation	Degrees of freedom	F	Signif. of F	Group means after adjusting for machinery size		
				* Map group	mean	N
					ha/hr	
Time to cultivate soil.	3	3.659	.017	Cmo 5	3.1	22
				Ags 8	3.4	25
				Cmo 4	3.7	19
				Ags 7	3.9	08
					l/hr	
Fuel to cultivate soil.	3	3.917	.065	Ags 7	17.93	10
				Cmo 4	22.94	18
				Ags 8	23.27	21
				Cmo 5		
					l/ha	
Fuel requirements per hectare	3	4.952	.004	Ags 7	5.37	07
				Cmo 4	6.07	18
				Ags 8	7.01	21
				Cmo 5	8.06	19

* Groups with homogeneous means according to Duncan's Multiple Range Test are joined.

units. The Angus Ridge 7 unit required less fuel and time than the Angus Ridge 8 unit. This may be a result of areas of Gleysolic soils not being cultivated and/or harvested, or of extreme values among the relatively small number of observations for the Angus Ridge 7 unit. The Camrose 5 unit had significantly greater fuel and time requirements than other units. Ambiguity of the relative positions of variable means on some soil map units may be a result of the estimated nature of the values used. Alternatively there may be very little difference between these variables for some soil map units.

The questionnaire also attempted to discover if certain map units required different numbers of cultivations and equipment passes to produce a crop. This would be an important consideration in assessing relative productivity of soil map units if it were the case. Farmers were asked to estimate the number of times they had to work each quarter section of land to produce a grain crop, rapeseed, and to work areas left in summerfallow. Results of Chi-square contingency table testing are given in Table 16. Although there appeared to be no relationship between the number of times grain crops were worked and the soil map unit it was grown on, the same cannot be said for rapeseed and summerfallow (Tables 17 and 18).

For rapeseed (Table 17), Angus Ridge 7 and Camrose 3 are more likely than expected to get a low number of cultivations, while Angus Ridge 8 and Camrose 5 units are

Table 16. Results of Chi-square Testing of Number of Cultivations needed on Soil Map Units.

Level of significance=.10.

Variable	Chi-square value	Degrees of freedom	Results
Times over grain	12.2	12	Cannot reject hypothesis of independence of times over grain and soil map units.
Times over rapeseed.	15.3	8	Must reject hypothesis of independence of and soil map units.
Times over summerfallow	15.4	8	Must reject hypothesis of times over summerfallow and soil map units.

Table 17. Deviations From Expected Frequencies. Times Rapeseed Worked.

Times crop worked	Ags 7	Ags 8	Cmo 3	Cmo 4	Cmo 5
6 or less	+1.7	-3.5	+4.7	+0.1	-2.9
7	-1.6	+1.5	-1.8	-0.6	+2.6
8 or more	-0.1	+2.0	-2.9	+.5	+.3

Table 18. Deviations From Expected Frequencies. Times summerfallow Worked.

Times fallow worked	Ags 7	Ags 8	Cmo 3	Cmo 4	Cmo 5
5 or less	-1.1	-3.1	+2.7	+4.3	-2.8
6	-1.7	+1.7	+0.5	+1.0	+1.6
7 or more	+2.8	+2.4	-2.2	-5.3	+2.2

more likely than expected to get a high number of workings. That the two Angus Ridge units do not behave in the same manner is puzzling. One would intuitively expect Black Solodized Solonetzic units to require more cultivations because of the adverse structure of the Solonetzic B horizon. Presence of a significant proportion of Gleysols does not appear to be relevant either, as Angus Ridge 7, Camrose 3 and Camrose 5 units all have a significant Gleysolic component.

There are several possible explanations:

1. Data may not be representative. Angus Ridge 7 and Camrose 5 units had only 11 and 10 observations respectively, and results may be unduly influenced by a few farmers' estimates;
2. The relationship could well be a spurious one, the number of workings for rapeseed being a function of some variable other than soil map units, but correlated in some way to them. It is difficult to speculate as to what this variable might be. Size of farm for example might reflect the intensity of management, but it has already been shown to be independent of soil map units.
3. As rapeseed has become a common crop in the study area only within the last five years, some farmers may not have developed optimal management practices yet. This could enter a considerable amount of inconsistency into the relationships between the number of times the soil is worked, and soil map units.

Results of testing the numbers of times summerfallow was worked on various soil map units given in Table 18 were a little more consistent. Angus Ridge 7 and 8 units were more likely than expected to receive an average or greater than average number of cultivations, as was the Camrose 5 unit. Camrose 3 and 4 units were more likely to receive a less than average number of workings. Two explanations may be presented to account for the fact that Angus Ridge 7 & 8 units receive a greater than expected number of cultivations when summerfallowed:

1. Angus Ridge units, being generally more productive, may have a better growth of weeds as well. They may require more frequent cultivation;
2. Angus Ridge map units may be managed more intensively than Camrose because the chances of getting a high yield are greater.

It is difficult to explain why the Camrose 5 unit should receive a higher than average number of cultivations when the other Camrose units do not.

Farmers were questionned about problems arising from soil conditions which create a problem to management. Fifteen per cent of them reported farming quarters which were either excessively difficult to cultivate in early spring, or were often hard to harvest because of wet weather in the fall. When tested using Chi-square contingency table, no relationship between soil map units and the existence of a problem could be found, nor could any ranking of soil map

units with respect to the presence of a problem be established. This was not expected. It could indicate a failure of the soil map units to adequately delineate soils with such problems.

Farmers were also asked to estimate the number of years in ten in which crop yields were sufficiently low that no returns to production were received, because of either excessively dry or wet weather conditions. These results could not be analyzed statistically by map unit, as too few farmers reported no returns to production costs in the past 10 years. However, all farmers who did report no returns were all farming Black Solodized Solonetzic soil map units. No farmer reported recieving no returns to crop roduction because of excessively wet or dry weather on either Black Chernozemic or Black Solodic soil map units.

This result may be important as it indicates that productivity of Black Solodized Solonetzic soil map units are more susceptible to extremes of climate than Black Chernozemic map units.

VI. Summary and Conclusions

Several conclusions can be drawn from the analyses of crop yield and soil management input data on different soil map units and groups of soil map units. Means of crop yields of wheat, barley and rapeseed vary most significantly between soil map unit groupings based on dominant soil series. For oat yield means, soil map unit groupings based on the presence of a significant Gleysolic component varied most significantly.

A provisional productivity index, like the performance index of Hoffman(1978) can be formulated on the basis of these results. If the productivity of the Angus Ridge units is taken as unity, Camrose units would have a productivity index of approximately .90 for wheat, barley and rapeseed, indicating that approximately 90% of the yield of Angus Ridge soil map units can be expected on Camrose soil map units. For oats, a soil map group with both Angus Ridge and Camrose soils and a significant Gleysolic component would have a productivity index of approximately .83, based on an index of 1.0 for a similar group without significant Gleysols. Soil map units with significant Gleysolic components can be expected to produce 83% of the oat yield of their counterparts without Gleysols.

It is interesting to compare these results with those derived by Hoffman(1978) for various crops in southern Ontario (Table 19). In agro-climatic region 1 in Alberta which includes the study area, Black Solodized Solonetz

Table 19. Comparison of Hoffman's Performance Indices to "Productivity Ratings".

CLI Capability Classes	Performance Index (Hoffman 1978)	Productivity Ratings: Wheat, Barley Rapeseed (Dom. soil series groups)	Productivity Ratings: Oats (groups with/ without Gleysols)
1	1.00	1.00 (Ags units)	1.00 (units without Gleysols)
2	.80	.90 (Cmo units)	.83 (units without Gleysols).

soils, with a thick Ah horzon, such as the Camrose soils, are generally rated 2d, according to the Canada Land Inventory System (Brocke 1977; Peters 1977). Black Chernozemic soils, like those of the Angus Ridge series are rated 1. The 10% reduction in yields on Camrose units, over Angus Ridge units is considerably less than the 20% reduction expected from Hoffman's study on class 2 land over class 1 land in southern Ontario. Cultivated Gleysols in the study area would likely be rated 2w in the Canada Land Inventory System. The 18% yield reduction for oats on soil map units with a Gleysolic component is more compatible with Hoffman's results. However, oat yields were reduced on map units where Gleysols were not the dominant soil. This reduction is therefore greater than would be expected from Hoffman's results in southern Ontario.

It is interesting that soil map units themselves appear to reflect crop productivity more poorly than groupings of units by dominant soil series. Yield differences between the various soils of the area, discernible with the data in hand do exist. Two possibilities must be considered:

1. Soil map units, as distinguished by a semi-detailed soil survey do not adequately delineate areas of equal crop yield; or
2. Yield differences which exist are too small to be distinguished with the data used.

If resolution of crop yield data is not good enough to discern yield differences on individual map units, variation

in yield figures due to farmers estimations may in fact be greater than variation in yields due to differences in map units. If this is the case, it is unlikely that differences in yields between map units exceeds 5 bu/A.

If scale of soil mapping used was not adequate for the delineation of areas of uniform crop productivity, there are two possibilities:

1. Soils are overmapped. Yield differences in soil map units being mapped at the semi-detailed level are not great enough to affect the farmers reported yields. If this is the case, the conclusion may be drawn that the variation in yield estimates used in this study is compatible with a soil survey which distinguished only the dominant soil series:
2. Soils are undermapped. Differences in soil characteristics reflecting variations in crop yields have not been adequately distinguished at the semi-detailed level.

It is possible that a scale of mapping of 1:50 000 is too detailed to allow broad generalization about crop productivity, but not detailed enough to separate smaller yield differences.

Only one conclusion can be drawn from the results of least-squares regression analysis. Yield predictions cannot be made using soil characteristics as described by soil map units alone or using soil map unit groupings. Soils as described by soil map units or groups do not appear to have

a great deal of effect on crop yield variation. Fertilizer additions and year variables explained most of the crop yield variation in all cases.

Soil map units do not appear to affect land use decisions greatly in the study area. The type of farm operation, crop rotations used, and farmer's plans for the future are independent of map units.

There is some evidence that time and fuel requirements for the production of rapeseed, and cultivation of summerfallow may vary between map units, but relationships are not consistent. It is difficult to draw firm conclusions. Although the Camrose 5 unit consistently required more of both time and fuel, it is not possible to enter these results into any kind of productivity index. Crops grown on Black Solodized Solonetz units appear to be more susceptible to extremes of climate, especially excessive wetness or dryness.

There is some evidence that farm operations on Angus Ridge units are more profitable than those on Camrose units, if the condition of the farm house can be used as some indication of the relative profitability of the farm operation. However the relationship between condition of farm house may be spurious. Income from non-farm sources, age of farmer, personnal preferences and background all affect the state of the farm house.

Considering consistent differences in crop yield production on Angus Ridge and Camrose units, differences in

farm input, and the greater possibility of crop failure on Camrose units, it is probable that measurable differences in profitablity of operations on the various soil series groups of soil map units exist.

Evaluation of Findings and Suggestions for Further Study

Results and conclusions of this study must be considered provisional at best. A much larger study base is required for many map units, to produce a more representative sample of crop yield information. In addition, information from a wider range of soil map units of other soil series of Black Chernozemic and Black Solodized Solonetz soils, over a broader area of the province, is required.

Other soil variables affecting crop yield should be examined. Topography for example was not considered in this study as there was little topographic variation. In other parts of the province, it is more important. Depth of Ah horizon is probably an important determinant of crop yields. Analysis of crop yield information specific to soil map units of both "thick" and "thin" Black Chernozemic and Black Solodized Solonetzic soils is required.

Several problems exist in utilizing crop yield information such as the Hail and Crop Insurance Corporation data. Poor correlations using multiple least squares regression techniques could be a result of variation introduced into the data during collection. Levels of significance of some of the results of the analyses of

covariance indicate some merit in analyzing data of this nature. However, the scale of the soil map from which soil map units are derived must be compatible with the degree of error in crop yield values. Expected differences in yield between soil map units must be greater than the precision of yield estimates, if any relationship between the two is to be discerned.

The Hail and Crop Insurance Corporation data may be compatible with a much less detailed soil survey only. If such is the case, more accurate, soil map unit-specific yield data are vital to establishing crop yield-soil map unit relationships at the semi-detailed level and larger scales of mapping.

An examination of better estimates of crop yields with respect to soil map units mapped at a more detailed level is required if soil map units are to be reliably related to crop yields and farm inputs. A detailed analysis of soil variability within soil map units should be an integral part of such a study. Considering the success of some detailed European studies of this nature, (Cruikshank and Armstrong 1971; Lee and Ryan 1966; Vink 1960) such an undertaking would probably be very useful.

Better climatic data is urgently required in the province for any detailed work of this nature. The use of a "dummy" variable to account for yearly climatic variation works well in the absence of better information. However, it cannot take the place of detailed site-specific temperature

and precipitation data, particularly for more detailed studies.

Much potentially useful information is available from farmers. As with crop yield data, care must be taken to ensure that the degree of error introduced into farmers' estimates of variables, because of faulty memory, incomplete records, or inaccurate reporting, does not exceed the actual variation between map units. Ideally, groups of farmers should be monitored over extended periods of time to gather detailed reliable crop yield and management input data.

In this study, interviews of a larger number of farmers over a larger area would increase the number of soil map units examined, and impove estimates of variables. Data gathered over a longer period of time would have allowed closer correlation of farmers' input data to crop yield data. This would give a better indication of the relative productivity of these map units. Additional information of an economic nature, such as off-farm income, and income derived from crops being considered in the study would be useful additions to any future studies of this nature.

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Appendix 1

Crop Yield-Map Unit Survey Questionnaire.

Section 1. General Information.

Location of home quarter _ quarter _ section _ township _ range

Size of farm--area owned _ quarters _ sections _ acres

area rented _ quarters _ sections _ acres

How would you describe your operation?

What is your main income producer?

How many years of farming experience do you have? _ years _

How many years have you been farming at this location? _ years.

How many years have you been in this operation? _ years.

What level of education do you have? _ college _ university.

Do you think you will expand your operation within the next ten years? _yes, _ no.

if yes, By renting land? _ or by buying land? _ .

What do you think you will do with the farm when you retire?

_ pass it on to a son, or other relative

_ sell it

_ don't know.

Do you, or have you had crop insurance? _ yes _ no.

if yes, give details.

Estimated age of farmer _ .

Building Rating: house _ farm _ .

Section 2 Land Use

Consider these areas farmed:

#1 _ quarter, _ section, _ twnshp, _ rnge _ Area cropped

#2

#3

#4

#5

#6

How would you rate these quarters as to productivity? (best to worst)

Do you follow different crop rotation systems for these quarters?

What would a standard rotation scheme be?

What % remains in summer fallow each year?

Do you vary the crop rotation because of any soil characteristics?

Is your crop rotation scheme any different in any of the fields within:

quarter #1 _ yes, _ no.

quarter #2 _ yes, _ no.

quarter #3 _ yes, _ no.

How do they differ?

Does your rotation system vary according to:

_soil, _ weather, _ land rented or owned, _ location with respect to home quarter

_ other

How do you determine your rotation system?

_ have found it produces the best results from experience

_ it has been suggested as being a good system by an extension group like Alberta Agriculture.

_other

Section 3 Farm Inputs

What yields did you get off these quarters this year?

Quarter #1 _ wheat, _ barley, _ rape, _ oats bu/A

quarter #2 _ wheat, _ barley, _ rape, _ oats bu/A

quarter #3 _ wheat, _ barley, _ rape, _ oats bu/A

quarter #4 _ wheat, _ barley, _ rape, _ oats bu?A

quarter #5 _ wheat, _ barley, _ rape, _ oats bu/A

quarter #6 _ wheat, _ barley, _ rape, _ oats bu/A

Was this: _ Average, _ above average, _ below average

What yields did you get last year (1978)?

quarter #1 _ wheat, _ barley, _ rape, _ oats bu/A.

quarter #2 _ wheat, _ barley, _ rape, _ oats bu/A.

quarter #3 _ wheat, _ barley, _ rape, _ oats bu/A.

quarter #4 _ wheat, _ barley, _ rape, _ oats bu/A.

quarter #5 _ wheat, _ barley, _ rape, _ oats bu/A.

quarter #6 _ wheat, _ barley, _ rape, _ oats bu/A.

Was this _ average, _ above average, _ below average.

How do you decide on type and rate of fertilizer application?

_ experience, _ soil testing

_ recommendations of fertilizer distributors

_ extension information from government agencies

_ what's being used in the area

_ other

Do you vary the rate of fertilizer application from year to

year?

Do you apply different rates to different quarters?

How much and what type of fertilizer did you apply to your land this year to produce:

wheat

barley

rapeseed

Does this differ on any of these quarters?

Do you vary the amounts or types of sprays applied to any of these quarters?

Do you have to work the land the same number of times to produce these crops on each of these three quarters?

How many times on the average?

grains _____

rape ______

Does it take you different lengths of time to work these quarters?

How many hours would it take you to work these quarters?

Using what equipment? _____ hp tractor _____ width cultivator

How much fuel per hour?__________

How many times per year do you work your fallow?______

Do you notice any difference in wear on farm implements when working any of these quarters? ____

Estimated extra cost _____

Do any of these quarters cause more problems than the others such as problems in getting on the land in the spring,

or getting crops off in the fall?

How many years in 10 have you received no returns to production because of either excessively wet or dry weather?

Codes for Management Data Derived from Questionnaires.

a. Legal location:

Township, Range, Section, Quarter section.

b. % of farm in summerfallow.

99 = no response.

c. Soils are an important factor in deciding upon crop rotation system.

0 = no

1 = yes

9 = no response

d. Number of years to complete one crop rotation.

9=no response

e. Soil testing used to decide upon fertilizer requirements.

1 = regularly

2 = occasionally

3 = never

9 = no response

f. Fertilizer application varies from year to year.

0 = no

1 = yes

9 = no response

g. Fertilizer application varies from quarter to quarter.

0 = no

1 = yes

9 = no response

h. Soils are important in deciding upon fertilizer application.

0 = no

1 = yes

9 = no response

i. Number of times grain crops worked.

99 = no response

j. Number of times rapeseed crops worked.

99 = no response

k. Number of times summerfallow worked.

99 = no response

l. Estimate of time required for cultivation.

99 = no response

m. Width of cultivator (feet).

99 = no response

n. Horsepower of tractor.

999 = no response

o. Fuel requirements for cultivation of summerfallow (gal./hr.).

999 = no response

p. Soil is difficult to manage.

0 = no

1 = yes

9 = no response

q. Number of years in 10 crop lost to dry weather.

9 = no response

r. Number of years in 10 crop lost to wet weather.

9 = no response

s. Age group of farmer.

1 = 25 to 35

2 = 35 to 45

3 = 45 to 55

4 = 55 to 65

6 = over 65.

t. Agricultural training.

0 = none

1 = college or university

2 = extension courses

u. Farmer is planning on expanding in the next 10 years.

0 = no

1 = yes

2 = maybe

v. Farm will remain in family upon present farmer's retirement.

0 = no

1 = yes

2 = maybe

w. Main farm income producer.

1 and 5 = mixed farm

2 = dairy

3 = grain

4 = beef

6 = hogs

7 = eggs and chickens

8 = general livestock.

x. Building ratings: farm, house.

rated poor to good on a scale of 1 to 5.

y. Total number of quarter sections farmed.

z. Dominant soil series of soil map unit.

1 = Angus Ridge

2 = Camrose

3 = Killam

4 = Tofield

z'. Map unit number.

Management Input Data from Questionnaires

a		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	z'
491504	NE	33	0	03	2	0	0	0	06	99	09	99	99	999	999	0	0	0	2	0	0	1	3	34	05	17	
491504	SW	33	0	03	2	0	0	0	06	99	09	99	99	999	999	0	0	0	2	0	0	1	3	34	05	17	
491506	NE	33	0	03	3	0	0	0	06	99	07	10	20	120	5.0	0	0	0	2	0	0	2	5	34	06	18	
491506	SE	33	0	03	3	0	0	0	06	99	07	10	20	120	5.0	0	0	0	2	0	0	2	5	34	06	16	
491506	SW	33	0	03	3	0	0	0	06	99	07	10	20	120	5.0	0	0	0	2	0	0	2	5	34	06	1	
491507	NW	25	0	04	3	0	0	0	04	99	99	06	12	085	3.5	0	0	0	2	0	0	2	3	34	02	18	
491509	NE	99	0	99	3	0	0	0	04	99	05	08	24	097	3.5	1	0	0	3	0	2	1	2	44	07	27	
491509	NW	99	0	99	3	0	0	0	04	99	05	08	24	097	3.5	1	0	0	3	0	2	1	2	44	07	27	
491516	NE	25	0	04	2	0	0	0	99	99	99	20	35	444	999	1	0	0	2	9	1	2	4	44	16	27	
491516	SE	25	0	04	2	0	0	0	99	99	99	20	35	444	999	0	0	0	2	9	1	2	4	44	16	18	
491516	N	25	0	04	2	0	0	0	99	99	99	20	35	444	999	0	0	0	2	9	1	2	4	44	16	18	
491516	S	25	0	04	2	0	0	0	99	99	99	20	35	444	999	0	0	0	2	9	1	2	4	44	16	18	
491518	SW	25	0	04	3	0	0	0	04	99	99	06	12	085	3.5	0	0	0	2	0	0	2	3	34	02	18	
491519	NE	33	0	03	3	0	0	0	05	99	05	12	25	999	999	0	0	0	5	0	0	1	4	44	07	17	
491519	SE	33	0	03	3	0	0	0	05	99	05	12	25	999	999	0	0	0	5	0	0	1	4	44	07	27	
491520	NW	33	0	03	3	0	0	0	09	99	05	09	16	087	999	0	0	0	1	0	0	2	5	33	03	17	
491520	SW	33	0	03	3	0	0	0	09	99	05	09	16	087	999	0	0	0	1	0	0	2	5	33	03	27	
491522	NW	33	0	03	3	0	0	0	05	99	05	05	18	999	999	0	0	0	4	0	0	2	3	33	04	27	
491522	SW	33	0	03	3	0	0	0	05	99	05	05	18	999	999	0	0	0	4	0	0	2	3	33	04	27	
491528	NE	33	0	03	3	0	0	0	05	99	05	06	18	999	999	0	0	0	4	0	0	2	3	33	04	17	
491528	NW	33	0	03	3	0	0	0	05	99	05	06	18	999	999	0	0	0	4	0	0	2	3	33	04	17	
491530	NW	33	0	03	3	0	0	0	05	99	05	09	19	999	999	1	0	0	4	0	0	1	3	44	02	1	
491530	SW	33	0	03	3	0	0	0	05	99	05	11	19	999	999	0	0	0	4	0	0	1	3	44	02	1	
491532	NE	33	0	03	3	0	0	0	05	99	05	12	25	999	999	0	0	0	5	0	0	1	4	44	07	1	
491532	NW	33	0	03	3	0	0	0	05	99	05	12	25	999	999	0	0	0	5	0	0	1	4	44	07	1	
491532	SE	33	0	03	3	0	0	0	05	99	05	12	25	999	999	0	0	0	5	0	0	1	4	44	07	1	
491601	SE	33	0	03	3	0	0	0	05	05	07	06	16	090	3.5	0	0	0	3	0	0	2	5	33	04	15	
491601	SW	33	0	03	3	0	0	0	06	99	99	15	27	172	10.0	9	0	0	2	0	0	1	3	34	07	15	
491602	NE	33	0	03	3	0	0	0	06	99	99	12	27	172	12.5	9	0	0	2	0	0	1	3	34	07	2	
491606	NW	00	1	00	1	0	0	1	08	08	99	99	99	444	999	0	0	0	2	0	2	2	4	44	10	17	
491607	NW	00	1	00	1	0	0	1	09	09	99	99	99	444	999	1	0	1	2	0	2	2	4	44	10	25	
491608	NE	33	0	03	3	0	0	0	07	99	08	07	20	109	5.0	1	0	0	3	0	0	1	2	44	07	25	
491608	SE	33	0	03	3	0	0	0	07	99	08	07	20	109	5.0	1	0	0	3	0	0	1	2	44	07	25	
491609	S	25	0	04	3	0	0	0	07	07	05	04	12	086	2.5	0	0	0	3	0	0	2	3	34	04	25	
491609	S	25	0	04	3	0	0	0	07	07	05	03	12	086	2.5	1	0	0	3	0	0	2	3	34	04	23	
491609	S	25	0	04	3	0	0	0	07	07	05	04	12	086	2.5	0	0	0	3	0	0	2	3	34	04	17	
491610	SW	33	0	03	3	0	0	0	07	99	08	08	20	109	4.0	0	0	0	3	0	0	1	2	44	07	17	
491611	SE	33	0	03	3	0	0	0	06	99	99	12	27	172	12.5	9	0	0	2	0	0	1	3	34	07	25	
491612	SW	33	0	03	3	0	0	0	06	99	99	12	27	172	12.5	9	0	0	2	0	0	1	3	34	07	25	
491615	SE	25	0	04	3	0	0	0	07	07	05	03	12	086	2.5	1	0	2	3	0	0	2	3	34	04	27	
491615	SW	25	0	04	3	0	0	0	07	07	05	03	12	086	2.5	1	0	2	3	0	0	2	3	34	04	2	
491620	E	99	0	99	3	0	0	0	04	99	05	09	24	097	3.5	0	0	0	3	0	2	1	2	44	07	18	
491621	S	99	0	99	3	0	0	0	04	99	05	09	24	097	3.5	0	0	0	3	0	2	1	2	44	07	18	
491621	S	99	0	99	3	0	0	0	04	99	05	09	24	097	3.5	1	0	0	3	0	2	1	2	44	07	26	
491622	NW	50	0	02	3	0	0	0	05	99	07	99	25	110	4.0	0	0	0	4	0	0	1	3	34	02	17	
491623	NE	33	0	03	3	0	0	0	04	99	05	13	30	160	6.5	0	0	0	4	0	0	1	4	44	08	18	
491625	NE	33	0	03	3	0	0	0	04	99	05	09	30	160	6.5	0	0	0	4	0	0	1	4	44	08	1	
491627	SW	50	0	02	3	0	0	0	05	99	07	99	25	110	4.0	1	0	0	4	0	0	1	3	34	02	17	

a		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	zz'
491629	NE	33	0	03	3	0	0	1	07	07	99	20	32	160	8.0	0	0	0	3	0	1	1	5	44	09	29
491629	SE	33	0	03	3	0	0	1	07	07	99	20	32	160	8.0	0	0	0	3	0	1	1	5	44	09	29
491631	SW	33	0	03	2	0	0	0	07	99	04	08	19	095	5.5	0	0	0	3	0	0	2	3	33	05	2
491632	NW	25	1	04	3	1	1	1	06	06	07	08	23	135	5.5	9	0	0	3	1	0	1	2	45	13	27
491632	SE	33	0	03	3	0	0	1	07	07	99	20	32	160	8.0	1	0	0	3	0	1	1	5	44	09	2
491633	NE	99	1	99	3	0	0	0	06	07	07	09	20	097	4.5	0	0	0	2	0	0	2	2	34	04	15
491633	NW	50	0	02	3	0	0	0	99	99	99	05	12	075	999	1	0	1	5	0	2	1	5	22	03	27
491633	SW	50	0	02	3	0	0	0	99	99	99	05	12	075	999	0	0	0	5	0	2	1	5	22	03	2
491634	SE	50	0	99	3	0	0	0	04	06	04	10	16	065	999	0	0	0	4	0	0	1	3	33	01	15
491636	SE	33	0	03	3	0	0	0	04	99	05	13	30	160	6.5	0	0	0	4	0	0	1	4	44	08	15
491636	SW	33	0	03	3	0	0	0	04	99	05	13	30	160	6.5	0	0	0	4	0	0	1	4	44	08	15
491702	NE	33	0	03	3	0	0	0	04	99	05	04	10	080	2.0	0	0	0	4	0	0	1	4	22	03	25
491702	SW	33	0	03	3	0	0	0	04	99	05	05	10	080	1.5	0	0	0	4	0	0	1	4	22	03	18
491703	NW	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1		14	44	08	12
491703	SE	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1	1	4	44	08	18
491703	SW	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1	1	4	44	08	12
491704	NE	99	0	99	3	0	0	0	05	99	99	99	99	999	999	0	0	0	5	0	0	2	4	22	03	1
491704	NW	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1	1	4	44	08	17
491705	NW	33	0	03	3	0	0	0	07	99	08	99	15	075	2.0	0	0	0	3	0	0	2	3	23	03	17
491705	SE	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1	1	4	44	08	29
491705	SW	33	0	03	3	0	0	0	07	99	08	99	15	075	2.0	1	0	0	3	0	0	2	3	23	03	25
491706	NW	33	0	03	3	0	0	0	07	99	08	99	15	075	2.7	1	0	0	3	0	0	2	3	23	03	2
491707	NW	16	0	06	2	0	0	0	07	08	06	11	25	108	5.0	1	0	0	2	0	1	1	3	34	06	24
491708	NE	16	0	06	2	0	0	0	07	08	06	12	25	108	4.0	0	0	0	2	0	1	1	3	34	06	17
491708	SE	16	0	06	2	0	0	0	07	08	06	12	25	108	4.0	1	0	0	2	0	1	1	3	34	06	17
491709	NE	99	0	99	3	0	0	0	05	99	99	99	99	999	999	0	0	0	5	0	0	2	4	22	03	18
491709	SE	99	0	99	3	0	0	0	05	99	99	99	99	999	999	0	0	0	5	0	0	2	4	22	03	12
491710	SW	20	0	05	3	0	0	0	07	06	04	18	26	135	7.0	0	0	0	3	2	1	1	4	44	08	1
491712	NW	00	1	00	1	0	0	1	08	08	99	99	99	444	999	0	0	0	2	0	2	2	4	44	10	25
491714	NE	33	0	03	3	0	0	0	07	99	04	07	10	080	3.5	0	0	0	4	0	0	2	3	22	02	24
491714	SE	33	0	03	3	0	0	0	07	99	04	07	10	080	3.0	0	0	0	4	0	0	2	3	22	02	28
491716	NW	33	0	03	3	0	0	0	08	10	08	04	16	100	3.8	1	1	9	1	0	1	2	6	34	01	25
491716	NW	33	0	03	3	0	0	0	08	10	08	05	16	100	3.0	0	0	9	1	0	1	2	6	34	01	18
491716	SE	33	0	03	3	0	0	0	07	07	07	09	16	100	5.5	0	0	0	3	0	0	2	5	44	01	1
491717	NE	16	0	06	2	0	0	0	07	08	06	12	25	108	4.0	0	0	0	2	0	1	1	3	34	06	18
491717	SE	16	0	06	2	0	0	0	07	08	06	12	25	108	4.0	0	0	0	2	0	1	1	3	34	06	1
491717	SW	16	0	06	2	0	0	0	07	08	06	12	25	108	4.0	0	0	0	2	0	1	1	3	34	06	1
491719	SW	99	0	99	2	0	0	0	08	99	99	10	20	999	4.5	0	0	0	1	1	1	2	6	44	06	45
491720	SE	33	0	03	3	0	0	0	07	11	06	15	27	180	6.0	0	0	0	4	0	1	1	3	44	03	1
491721	NE	33	0	03	3	0	0	0	07	11	06	13	27	180	6.0	0	0	0	1	0	1	2	3	44	04	28
491721	NW	99	0	99	2	0	0	0	08	99	99	10	20	999	4.5	0	0	0	1	1	1	2	6	44	06	17
491721	SE	33	0	03	3	0	0	0	07	11	06	15	27	180	6.0	0	0	0	1	0	1	2	3	44	04	17
491723	NW	33	0	03	2	0	0	0	07	99	04	08	19	095	5.5	0	0	0	3	0	0	2	3	33	05	24
491724	NE	25	0	04	3	0	0	0	06	06	04	06	19	105	3.5	0	0	0	3	2	0	1	5	34	04	2
491724	NW	25	0	05	3	0	0	0	06	06	04	06	19	105	3.5	0	0	0	3	2	0	1	5	34	04	33
491725	SE	33	0	03	2	0	0	0	08	08	05	10	25	135	5.0	0	0	0	3	0	2	1	3	44	12	24
491726	NE	25	0	04	3	0	0	0	06	06	04	07	19	105	3.5	0	0	0	3	2	0	1	5	34	04	24
491726	NW	33	0	03	3	0	0	0	07	11	06	15	27	180	6.0	0	0	0	1	0	1	2	3	44	04	24
491726	SE	25	0	04	3	0	0	0	06	06	04	07	19	105	3.5	0	0	0	3	2	0	1	5	34	04	24
491728	NE	33	0	03	2	0	0	0	08	08	05	10	25	135	5.0	0	0	0	3	0	2	1	3	44	12	28

a		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	zz'
491728	SE	25	1	04	3	1	1	1	06	06	07	10	23	135	5.5	9	0	0	3	1	0	1	2	45	13	28
491728	SW	25	1	04	3	1	1	1	06	06	07	10	23	135	5.5	9	0	0	3	1	0	1	2	45	13	17
491730	NE	25	0	04	3	0	0	0	99	99	99	04	12	080	999	0	0	0	4	0	0	2	5	33	05	23
491731	NW	17	0	12	3	0	0	0	06	04	08	99	99	999	999	0	3	0	4	0	0	1	2	45	05	25
491731	NW	00	0	00	3	0	0	0	99	99	99	06	12	100	999	0	0	0	4	0	0	1	5	33	01	25
491731	SE	17	0	12	3	0	0	0	06	04	08	99	99	999	999	0	0	0	4	0	0	1	2	45	05	18
491732	NW	25	0	04	3	0	0	0	99	99	99	05	12	080	999	0	0	0	4	0	0	2	5	33	05	18
491732	SE	25	1	04	3	1	1	1	06	06	07	10	23	135	5.5	9	0	0	3	1	0	1	2	45	13	18
491732	SW	25	0	04	3	0	0	0	99	99	99	05	12	080	999	0	0	0	4	0	0	2	5	33	05	18
491733	SE	33	0	03	2	0	0	0	08	08	05	10	25	135	5.0	1	0	1	3	0	2	1	3	44	12	2
491734	SE	25	0	04	3	0	0	0	08	08	06	99	20	110	999	0	0	0	3	0	0	1	5	45	05	18
491734	SW	33	0	03	2	0	0	0	08	08	05	10	25	135	5.0	0	0	0	3	0	2	1	3	44	12	28
491801	NW	33	0	03	3	0	0	0	05	99	05	02	10	999	3.0	0	0	0	5	0	0	2	3	23	0	25
491802	N	33	0	03	3	0	0	0	08	99	06	09	21	110	4.0	0	0	0	1	0	1	2	3	23	04	2
491802	S	33	0	03	3	0	0	0	08	99	06	09	21	110	4.0	0	0	0	1	0	1	2	3	23	04	23
491802	N	33	0	03	3	0	0	0	08	99	06	09	21	110	4.0	0	0	0	1	0	1	2	3	23	04	25
491802	S	33	0	03	3	0	0	0	08	99	06	08	21	110	4.0	0	0	0	1	0	1	2	3	23	04	25
491802	N	33	0	03	3	0	0	0	08	99	06	09	21	110	4.0	0	0	0	1	0	1	2	3	23	04	25
491802	S	33	0	03	3	0	0	0	08	99	06	09	21	110	4.0	0	0	0	1	0	1	2	3	23	04	24
491803	SE	00	1	00	1	0	1	1	07	05	05	19	31	175	10.0	1	0	0	2	0	1	1	3	44	08	24
491803	SW	00	1	00	1	0	1	1	07	05	05	19	31	175	10.0	1	0	0	2	0	1	1	3	44	08	24
491804	SE	33	0	03	2	0	0	0	05	04	05	05	14	045	1.5	0	0	0	2	0	0	2	5	43	03	24
491808	NE	25	0	04	3	0	0	0	05	99	05	05	16	100	999	0	0	0	3	0	1	1	5	43	04	24
491808	SE	25	0	04	3	0	0	0	05	99	05	05	16	100	999	0	0	0	3	0	1	1	5	43	04	25
491810	SE	33	0	03	3	0	0	0	07	99	05	99	99	999	999	0	0	0	4	0	0	1	4	33	04	2
491810	SW	33	0	03	3	0	0	0	07	99	05	99	99	999	999	0	0	0	4	0	0	1	4	33	04	24
491811	NE	33	0	03	3	0	0	0	07	99	05	99	99	999	999	0	0	0	4	0	0	1	4	33	04	23
491811	SE	33	0	03	3	0	0	0	07	99	05	99	99	999	999	0	0	0	4	0	0	1	4	33	04	23
491812	SE	33	0	03	3	0	0	0	05	99	06	06	12	085	4.0	0	0	0	3	0	1	1	4	32	06	24
491812	SW	33	0	03	3	0	0	0	05	99	05	02	10	999	3.0	0	0	0	5	0	0	2	3	23	02	23
491813	SW	25	0	04	3	0	0	0	05	07	05	09	25	999	999	0	0	0	2	0	1	1	5	43	07	15
491814	NE	33	0	03	3	0	0	0	05	99	06	06	12	085	4.0	0	0	0	3	0	1	1	4	32	06	24
491820	NE	25	0	04	3	0	0	0	05	99	05	04	16	100	999	0	0	0	3	0	1	1	5	43	04	23
491823	NE	33	0	03	3	0	0	0	99	99	99	09	24	999	4.0	0	0	0	4	0	0	1	4	43	03	25
491824	SW	17	0	12	3	0	0	0	06	04	08	99	99	999	999	0	0	0	4	0	0	1	2	45	05	45
491826	NE	99	0	99	2	0	0	0	08	99	99	10	20	999	4.5	0	0	0	1	1	1	2	6	44	06	45
491827	SE	99	0	99	3	0	0	0	99	99	99	09	24	999	4.0	0	0	0	4	0	0	1	4	43	03	44
491829	SW	30	1	05	9	0	0	0	06	08	05	05	26	100	999	0	9	9	4	0	0	2	4	44	05	16
491829	W	30	1	03	9	0	0	0	06	08	05	02	26	100	999	1	9	9	4	0	0	2	4	44	05	53
491832	NW	00	1	00	2	0	0	0	05	07	99	15	24	999	999	9	9	9	2	0	1	2	2	44	06	1
491836	SE	17	0	12	3	0	0	0	06	04	08	99	99	999	999	0	0	0	4	0	0	1	2	45	05	25
501606	NW	33	0	03	2	0	0	0	07	99	04	08	19	095	5.5	0	0	0	3	0	0	2	3	33	05	18
501606	SW	33	0	03	2	0	0	0	07	99	04	08	19	095	5.5	0	0	0	3	0	0	2	3	33	05	18
501607	SE	25	0	04	3	0	0	0	06	07	05	10	19	090	4.0	0	0	0	3	2	1	1	2	44	08	1
501607	SW	25	0	04	3	0	0	0	06	07	05	10	19	090	4.0	0	0	0	3	2	1	1	2	44	08	1
501608	NE	33	0	03	3	0	0	0	05	99	06	10	99	999	999	0	9	9	3	0	0	1	5	33	03	26
501609	NE	33	0	03	3	0	0	0	06	99	04	07	21	108	3.5	1	0	0	2	0	0	1	1	44	04	15
501609	SE	33	0	03	3	0	0	0	06	99	04	07	21	108	3.5	0	0	0	2	0	0	1	1	44	04	1
501702	NE	25	0	04	3	0	0	0	08	08	06	99	20	110	999	0	0	3	3	0	0	1	5	45	05	25
501702	SE	33	0	03	3	0	0	0	05	99	06	10	99	999	999	0	9	9	3	0	0	1	5	33	03	18

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	zz'
501702 SW	33	0	03	3	0	0	0	05	99	06	07	99	999	999	0	9	9	3	0	0	1	5	33	03	25
501703 NE	25	0	04	3	0	0	0	08	08	06	99	20	110	999	0	0	0	3	0	0	1	5	45	05	23
501703 NW	25	0	04	3	0	0	0	08	08	06	99	20	110	999	0	0	0	3	0	0	1	5	45	05	23
501704 SW	30	0	04	2	0	0	0	06	99	06	10	27	175	8.0	0	0	0	2	0	1	2	2	43	08	18
501706 NW	00	1	00	3	0	0	0	08	99	05	99	21	130	999	0	0	0	1	0	0	2	2	44	07	2
501706 SE	33	0	03	2	0	0	0	08	08	05	10	25	135	5.0	0	0	0	3	0	2	1	3	44	12	2
501706 SW	33	0	03	2	0	0	0	08	08	05	08	25	135	5.0	0	0	0	3	0	2	1	3	44	12	2
501707 SE	30	0	04	2	0	0	0	06	99	06	10	27	175	8.0	0	0	0	2	0	1	2	2	43	08	46
501707 SW	25	1	04	3	0	0	0	06	99	05	03	10	060	2.0	0	0	0	3	0	0	0	3	33	02	46
501709 NE	25	1	04	3	1	1	1	06	06	07	08	23	135	6.5	9	2	5	3	1	0	1	2	45	13	2
501709 NW	25	1	04	3	1	1	1	06	06	07	08	23	135	6.5	9	2	5	3	1	0	1	2	45	13	25
501709 SE	25	1	04	3	1	1	1	06	06	07	08	23	135	6.5	9	2	5	3	1	0	1	2	45	13	2
501709 SW	25	1	04	3	1	1	1	06	06	07	08	23	135	6.5	9	2	5	3	1	0	1	2	45	13	25
501714 SE	50	0	02	3	0	1	0	08	99	99	05	12	115	5.0	0	9	0	2	0	0	2	2	44	02	25
501714 SW	00	0	00	3	0	1	0	08	99	99	05	12	115	5.0	0	9	0	2	0	0	2	2	44	02	25
501714 S	50	0	02	3	0	1	0	09	99	99	05	12	115	5.5	0	9	2	2	0	0	2	2	44	02	25
501715 NW	25	0	04	3	0	0	0	06	07	05	10	19	090	4.0	0	0	0	3	2	1	1	2	44	08	23
501715 SE	25	0	04	3	0	0	0	06	07	05	10	19	090	4.0	0	0	0	3	2	1	1	2	44	08	25
501716 NW	25	0	04	3	0	0	0	06	08	05	05	12	100	3.0	0	0	0	3	1	0	2	2	33	04	23
501717 NE	33	0	03	3	0	0	0	05	07	06	10	20	100	5.0	0	0	0	4	0	0	2	5	43	02	2
501717 NW	25	0	04	3	0	0	0	99	99	99	99	99	999	999	0	0	0	3	0	0	1	3	44	06	25
501717 SE	25	0	04	3	0	0	0	07	09	99	03	14	094	999	0	0	0	4	0	0	1	4	44	03	23
501717 SW	25	0	04	3	0	0	0	07	09	99	03	14	094	999	0	0	0	4	0	0	1	4	44	03	25
501718 NE	25	0	04	3	0	0	0	99	99	99	99	99	999	999	0	0	0	3	0	0	1	3	44	06	25
501720 NW	25	0	04	3	0	0	0	99	99	99	99	99	999	999	0	0	0	3	0	0	1	3	44	06	22
501720 NW	25	0	04	3	0	0	0	99	99	99	99	99	999	999	0	0	0	3	0	0	1	3	44	06	18
501720 SE	33	0	03	3	0	0	0	05	07	06	10	20	100	5.0	0	0	0	4	0	0	2	5	43	02	25
501721 SW	25	0	04	3	0	0	0	06	08	05	06	12	100	2.5	0	0	0	3	1	0	2	2	33	04	25
501722 SW	25	0	04	3	0	0	0	06	07	05	10	19	090	4.0	0	0	0	3	2	1	1	2	44	08	23
501726 NW	33	0	09	2	0	1	1	04	04	08	13	30	100	7.0	1	1	0	2	1	0	0	3	44	08	24
501727 NE	33	0	03	3	0	0	0	05	05	05	06	14	100	3.0	0	0	0	4	0	0	1	5	33	02	24
501727 NW	25	0	04	3	0	0	0	05	05	05	06	20	100	2.5	0	0	0	4	0	0	1	3	33	04	22
501727 SE	33	0	03	3	0	0	0	05	05	05	07	14	100	3.0	0	0	0	4	0	0	1	5	33	02	15
501727 SW	25	0	04	3	0	0	0	05	05	05	06	20	100	2.5	0	0	0	4	0	0	1	3	33	04	22
501728 NE	00	0	00	0	0	0	0	07	99	99	04	14	065	1.5	0	0	0	4	0	0	0	7	33	01	22
501728 NW	99	0	99	3	0	0	0	07	07	10	10	19	108	999	0	0	0	4	0	0	2	4	32	06	22
501729 NE	00	1	00	1	0	0	1	99	99	99	99	99	999	999	0	0	0	4	0	2	1	3	44	10	53
501729 SE	33	0	03	3	0	0	0	05	07	06	10	20	100	5.0	0	0	0	4	0	0	2	5	43	02	22
501730 SW	25	0	04	3	0	0	0	99	99	99	99	99	999	999	0	0	0	3	0	0	1	3	44	06	18
501732 NW	99	0	99	3	0	0	0	07	07	10	10	19	108	999	0	0	0	4	0	0	2	4	32	06	2
501732 SW	33	0	09	2	0	1	1	04	04	08	14	30	100	8.0	1	0	0	2	1	0	0	3	44	08	22
501733 NE	25	0	04	3	0	0	0	05	05	05	06	20	100	2.5	0	2	0	4	0	0	1	3	33	04	22
501733 SE	25	0	04	3	0	0	0	05	05	05	06	20	100	2.5	0	2	0	4	0	0	1	3	33	04	22
501733 SW	99	0	99	3	0	0	0	07	07	10	10	19	108	999	0	0	0	4	0	0	2	4	32	06	44
501734 W	33	0	09	2	0	1	1	04	04	08	15	30	100	7.0	0	0	0	2	1	0	0	3	44	08	2
501735 NE	25	1	04	1	1	1	1	07	99	99	07	14	100	3.0	0	0	0	3	2	0	1	3	43	05	24
501735 NW	25	1	16	1	1	1	1	07	99	99	06	14	100	4.0	1	0	0	3	2	0	1	3	43	05	2
501735 SE	25	1	16	1	1	1	1	07	99	99	06	14	100	4.0	1	0	0	3	2	0	1	3	43	05	24
501801 NW	00	1	00	3	0	0	0	08	99	05	99	21	130	999	1	0	0	1	0	0	2	2	44	07	22
501803 NW	00	1	00	2	0	0	0	05	07	99	15	24	999	999	9	9	9	2	0	1	2	2	44	06	18

a		b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	zz'
501803	SW	00	1	00	2	0	0	0	05	07	99	13	24	999	999	9	9	9	2	0	1	2	2	44	06	23
501804	NE	33	0	03	2	0	0	0	10	10	07	14	35	999	999	9	0	0	2	0	2	1	3	33	04	28
501805	W	25	0	04	3	0	0	0	06	07	08	07	14	075	4.7	0	0	0	1	0	1	2	5	43	02	18
501805	W	25	0	04	3	0	0	0	06	07	07	07	14	075	4.7	1	0	0	1	0	1	2	5	43	02	18
501805	W	25	0	04	3	0	0	0	06	07	07	07	14	075	3.5	0	0	0	1	0	1	2	5	43	02	16
501808	NW	25	1	04	3	0	0	0	05	06	06	13	16	090	4.8	0	0	0	3	0	1	3	2	34	03	24
501809	SE	33	0	03	2	0	0	0	08	08	06	14	35	999	999	9	0	0	2	0	2	1	3	33	04	18
501809	SW	33	0	03	3	0	0	0	05	07	05	99	99	999	999	0	0	0	3	0	2	2	3	99	07	18
501810	NW	33	0	03	2	0	0	0	08	08	06	14	35	999	999	9	0	0	2	0	2	1	3	33	04	18
501810	SW	33	0	03	2	0	0	0	08	08	06	14	35	999	999	9	0	0	2	0	2	1	3	33	04	18
501811	NW	00	0	04	3	0	0	0	03	07	99	10	29	001	999	9	9	9	5	0	0	1	5	44	12	18
501814	NE	20	0	05	3	1	1	0	05	06	06	09	17	100	4.0	9	9	9	3	0	0	1	2	44	07	44
501814	SW	00	0	04	3	0	0	0	03	07	99	09	29	001	999	9	9	9	5	0	0	1	5	44	12	18
501815	NE	20	9	00	3	0	0	0	08	08	07	06	20	100	4.5	0	9	9	3	0	0	9	3	44	05	18
501815	NW	33	0	03	3	0	0	0	05	05	99	06	20	999	999	9	9	9	4	0	0	1	5	33	03	18
501815	SE	20	9	00	3	0	0	0	08	08	07	06	20	100	4.5	0	9	9	3	0	0	9	3	44	05	18
501815	SW	20	9	00	3	0	0	0	08	08	07	06	20	100	4.5	0	9	9	3	0	0	9	3	44	05	18
501816	NW	33	0	03	3	0	0	0	05	07	05	99	99	999	999	0	0	0	3	0	2	2	3	99	07	24
501817	NW	00	0	00	3	0	0	0	06	06	99	27	43	444	7.5	0	0	0	3	0	1	1	3	44	08	25
501820	NW	33	1	03	3	0	1	0	06	99	05	04	10	999	2.5	0	0	0	3	0	1	1	1	44	03	24
501820	SW	33	1	03	3	0	1	0	06	99	05	04	10	999	2.5	0	0	0	3	0	1	1	1	44	03	25
501821	NE	00	0	02	3	0	1	0	07	99	99	08	16	094	5.0	0	0	0	2	0	2	2	7	44	02	18
501821	SW	33	0	03	3	0	0	0	05	05	99	05	20	999	999	9	9	9	4	0	0	1	5	33	03	23
501823	NE	20	0	05	3	1	1	0	05	06	06	08	17	100	5.0	9	9	9	3	0	0	1	2	44	07	25
501824	NW	25	0	04	3	0	0	0	07	99	05	05	16	100	5.5	0	0	0	2	0	0	1	5	43	04	2
501824	SE	25	0	04	3	0	0	0	07	99	05	05	16	100	5.5	1	0	0	2	0	0	1	5	43	04	2
501824	SW	00	0	00	3	0	0	0	07	99	05	05	16	100	5.5	0	0	0	2	0	0	1	5	43	04	2
501826	NW	00	0	00	3	0	0	0	07	07	99	99	99	999	999	0	0	0	3	0	0	2	3	43	04	44
501826	SE	20	0	05	3	1	1	0	05	06	06	09	17	100	4.0	9	9	9	3	0	0	1	2	44	07	45
501828	NW	33	0	03	0	0	0	0	05	99	06	99	99	999	999	0	0	0	3	0	0	2	2	22	01	18
501828	SW	00	0	02	3	0	1	0	07	99	99	08	16	094	5.0	0	0	0	2	0	2	2	7	44	02	18
501829	NW	00	0	00	3	0	0	0	06	06	99	27	43	444	7.5	0	0	0	3	0	1	1	3	44	08	24
501829	SE	33	0	03	3	0	0	0	05	07	05	99	99	999	999	0	0	0	3	0	2	2	3	99	07	24
501829	SW	33	1	03	3	0	1	0	06	99	05	04	10	999	2.5	0	0	0	3	0	1	1	1	44	03	24
501832	NE	25	0	04	2	0	0	0	06	06	06	12	24	999	5.0	0	9	9	1	0	0	2	6	45	07	24
501832	NW	25	0	04	2	0	0	0	06	06	06	13	24	999	5.0	0	9	9	1	0	0	2	6	45	07	24
501835	SW	00	0	00	3	0	0	0	06	07	99	99	99	999	999	0	0	0	3	0	0	2	3	43	04	44
501836	N	99	0	99	3	0	0	0	07	07	10	10	19	108	999	0	0	0	4	0	0	2	4	32	06	23

Appendix 2

Descriptive Statistics of Crop Yield Data

Crop	Mean bu/A	Standard Error	Standard Deviation
Wheat	30	0.6	10.9
Barley	39	1.1	20.4
Rapeseed	22	0.5	8.1
Oats	52	1.3	25.9